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Metal PROGRESS

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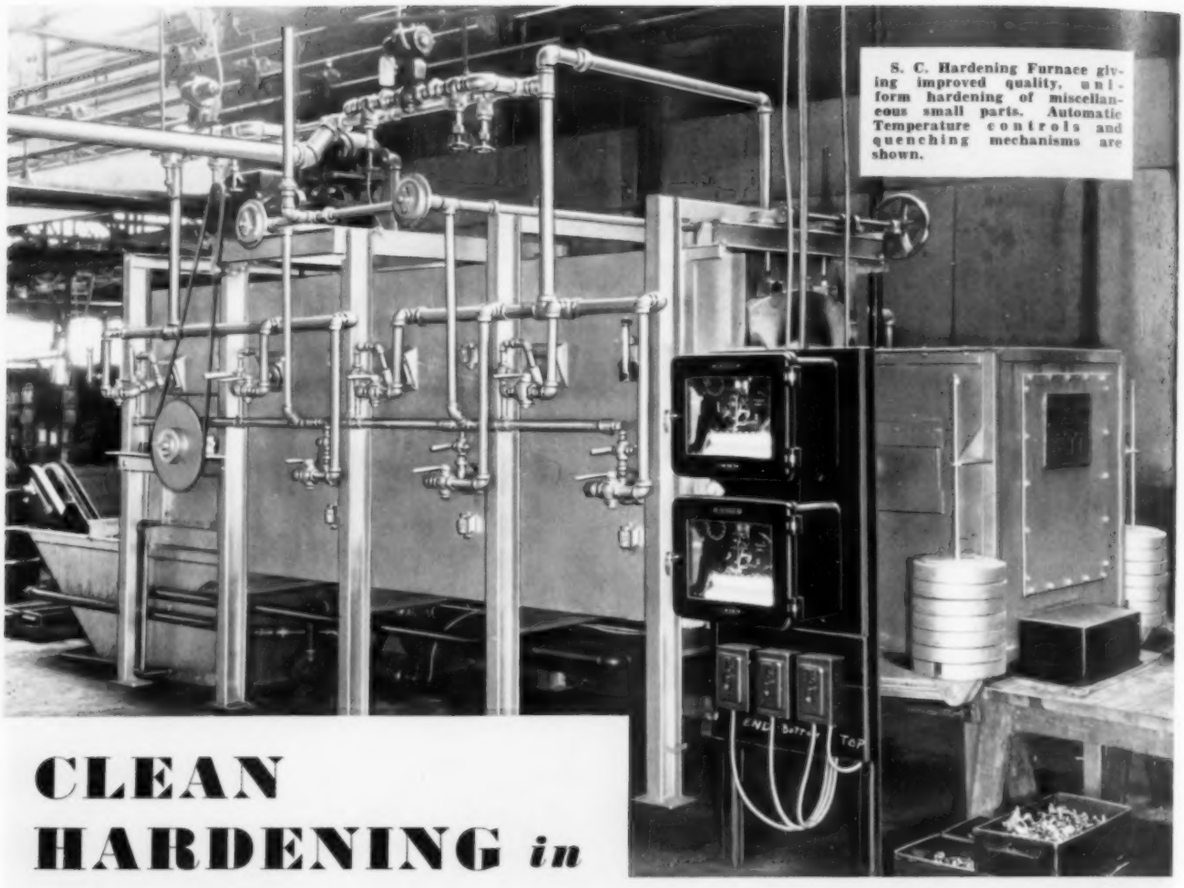

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METAL PROGRESS

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JUNE, 1935

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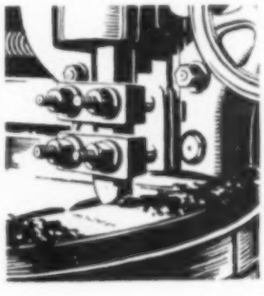
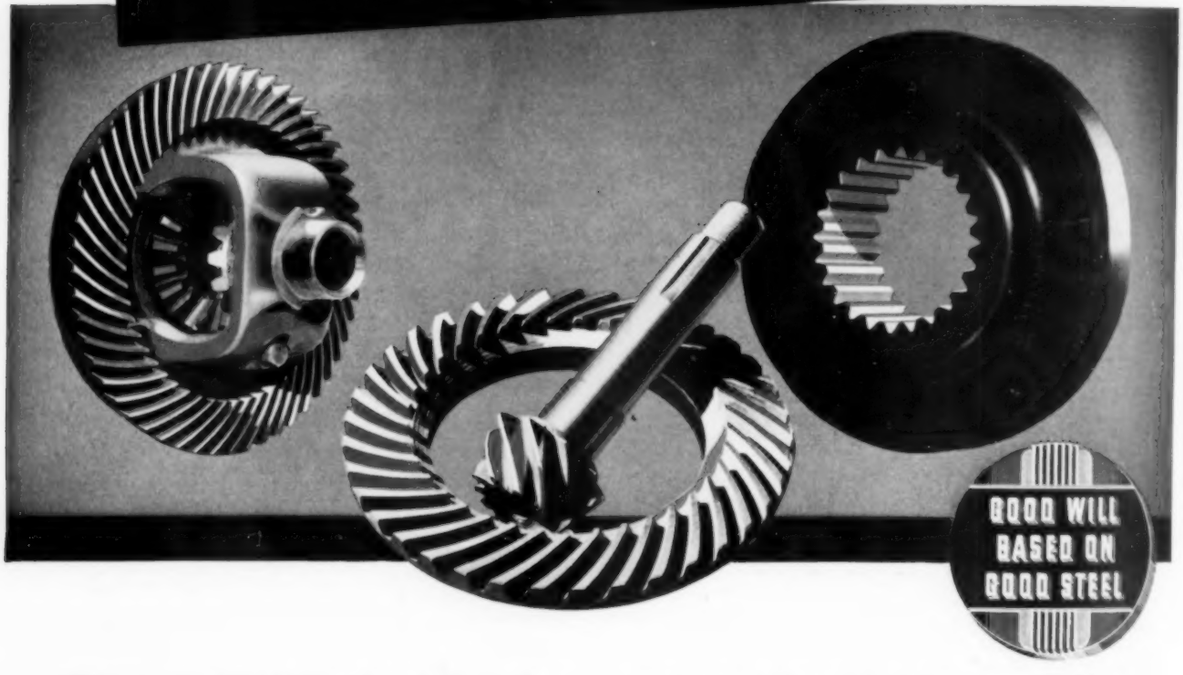
Ernest E. Thum, Editor



UNIFORM DISTORTION IN TIMKEN ALLOY STEELS *cuts gear costs*



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AGE HARDENED STEEL

avoided rather

than utilized

by Paul D. Merica
Assistant to President
International Nickel Co.,
New York

IN TWO FORMER ARTICLES (METAL PROGRESS FOR January and March) I have written principally of non-ferrous alloys in relation to precipitation hardening. Some readers will probably be tempted to ask, "Why, if this phenomenon is so successful and common amongst non-ferrous metals, hasn't it been found in ordinary steel?"

Well, the answer is, it has! Indeed, the history of age hardening in steel is a most curious one, and not too complimentary to our metallurgical intelligence. It was known as early as the 1890's that the magnetic properties of steel were subject to slow alteration at temperatures only slightly above ordinary ones. Early in this century the boiler plate manufacturers recognized that even the mechanical properties of mild steel were subject to gradual change, particularly after cold work or deformation. Thus, even before the discovery of duralumin in 1911, aging phenomena were actually observed in steel, and had they excited our curiosity only a bit more, they might have led to the elucidation of age hardening in connection with steel instead of with duralumin. But instead these embarrassing facts were merely regarded as taboo and hushed up in so far as possible.

The joke is an even better one when we realize that probably every bit of steel ever made is, under proper conditions, hardenable by aging — and it is safe to say that of all the metals, iron and steel are probably the most susceptible to this phenomenon. They seem, in fact, to be literally infested with it! It is there, and has always been there, for all to see who would. We have been too much impressed by martensitic hardening in steel to dream of any other kind!

Low Carbon Steel Hardens

Let us see what the facts are:

If a very soft steel, containing say 0.03 to 0.05% of carbon, is quenched from about 1300° F., well under its critical temperature, and tested from time to time thereafter, its hardness and strength will be found to increase — gradually, but by quite substantial amounts. Thus, in an actual case quoted by A. Allen Bates in *Transactions*, A.S.S.T., 1931, the hardness rose from 145 to 193 and the elastic limit from 53,700 to 77,900 psi. after 30 days at ordinary temperatures. This is quite an age hardening performance for such an unsuspected subject as ordinary sheet steel! Yet it appears to be quite characteristic of the material, although somewhat variable in actual magnitude.

From the fact that it is substantially absent in steels containing less than about 0.008% of carbon, and from other evidence as well, it seems reasonably certain that this age hardening is due to the segregation and precipitation of carbon in some form. At about 1300° F. carbon appears to

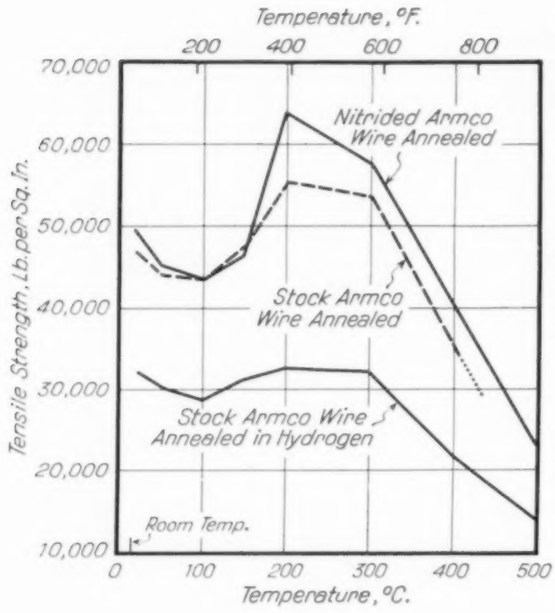
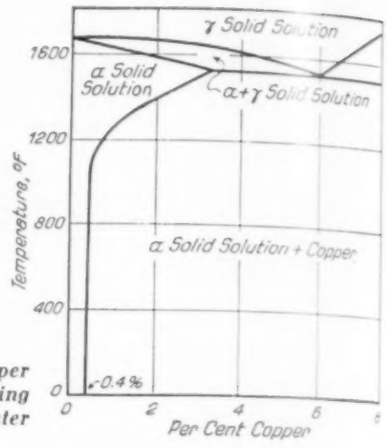


Diagram at Left Shows That Ingot Iron Wire, Deoxidized by Annealing in Hydrogen, Gains Little Strength at 500° F. Stock wire, and especially nitrided wire, has enhanced strength at about 500° F. Temperature and plastic deformation of testing seem to precipitate a strengthening constituent (Dean, Day and Gregg, 1929)



Solubility of Copper in Iron, According to Bucholz and Köster

be soluble in alpha iron to the extent of about 0.03%, but it is very much less soluble at lower temperatures. It would appear that alpha iron, supersaturated with carbon, slowly decomposes at ordinary temperatures by diffusion and segregation of carbon and this segregation is the cause of the age hardening observed. Incidentally, hardening in such a steel is substantially accelerated at temperatures from 200 to 400° F.

It will be at once obvious that this phenomenon should be detectable to a quite varying degree in steels of different carbon contents and in different conditions. It may often, perhaps generally, be obscured or even substantially eliminated by heat treatments designed for other purposes. It is probably for this reason that it escaped notice so successfully in the past.

Carbon, although the cheapest, is not the only hardening agent which will induce aging effects of this sort. It seems probable that iron nitride, as well as other impurities, exerts similar age hardening effects upon steel, as W. Köster, and others showed in *Archiv für das Eisenhüttenwesen*, 1930, page 637, and its solubility-temperature relations are such as to suggest that these effects are probably due to simple precipitation hardening. These hardening effects are quite noticeable in fusion welds in soft steel (F. R. Hensel and E. I. Larsen, *Transactions*, A.S.S.T., page 639, 1932) and are due to the presence of nitrides of iron introduced by absorption of nitrogen during arc welding. See also the above curve for ingot iron wire as to the effect of nitrogen.

Hardening by Copper

Copper does a fair job of hardening steel! As shown by the accompanying structural diagram, the solubility of copper in alpha iron at about 1500° F. is over 3%, whereas it diminishes to less than 0.5% at ordinary temperatures. C. S. Smith and E. W. Palmer have shown that by heat treating copper bearing steels, low in carbon, the hardness may be increased by as much as 50 points Brinell, and yield points by from 25,000 to 30,000 psi. (Their paper is printed in *Transactions*, A.I.M.E., 1933.)

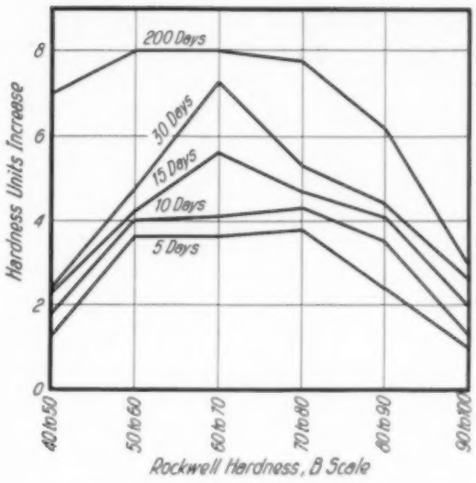
The heat treatment may consist of quenching followed by tempering, but in this case air cooling from 1300 to 1500° F. is usually adequate to suppress the normal precipitation of copper in the alpha iron.

Let me emphasize for a moment the interesting fact that copper bearing steel is hardenable by at least three different agencies and by three different types of heat treatment, each substantially independent of the others. First is ordinary martensitic hardening; the steel may be hardened by quenching from above 1650° F. and softened by tempering. Second is carbon precipitation hardening; the steel may be softened by quenching from about 1300° F. and hardened by aging at ordinary temperatures (opposite effects from similar treatments). Third is copper precipitation hardening; the copper bearing steel may be quenched soft from about 1400° F. and hardened by tempering at about 950° F. Here is truly a wealth of hardening possibilities!

Many other combinations are known, such as beryllium, boron, and aluminum plus nickel that will permit a hardening of the duralumin

type in such steels, and there must be many more that will act in the same manner.

As to its practical value in connection with steel, it is certainly too early to judge, since there is as yet practically no commercial use of it. It would seem, superficially, that one could not afford to pay much for the privilege of age hardening steel through the addition of more expensive elements such as copper, since plain steel does a very good job of hardening by itself and does it very cheaply. On the other hand, there is so much copper in the circulating load of automotive and machinery scrap (from which most of our present-day American steels are made) that we may be presented with this new hardening agent, willy nilly.



Low Carbon Steel Strip, Cold Rolled to Various Hardnesses by Commercial Mill Practice, Hardens Materially on Aging. Moderately severely worked material ages quickly; lightly worked material ages slowly at first but eventually gets nearly as hard; severely worked material ages very slightly (Whittemore)

Nevertheless, one can see certain advantages of precipitation hardening over the conventional kind, which in special cases may render it commercially economic. Thus, it offers the possibility of distortionless hardening which is attractive with its implication of cheaper fabrication. It is possible that large sections may be more uniformly hardened by the precipitation method, and with the development of less internal stress, than by the usual method, since the quenching treatment is not associated with any abrupt changes in volume of the material, and the tempering reaction occurs gradually and at uniform temperature throughout the whole section of the article being hardened.

At any rate there is an active commercial interest in the subject of high strength, low alloy steels just now, and we shall undoubtedly be in position within the near future to capitalize more fully any advantages of the newer art which may prove economic for steel.

Other Steel "Aging" Phenomena

Now, most unfortunately, internal precipitations in steel have their bad side as well as good. I hardly need remind you that it is generally recognized that temper brittleness or "Krupp Krankheit" is caused by a precipitation of some sort in steel, either during slow cooling from tempering temperatures around 1200° F. or during tempering at temperatures 200 or 300° lower. It seems fairly certain, from the work of J. H. Whiteley and other Englishmen, published since 1926 in *Journal* of the Iron & Steel Institute, that this precipitation may pretty generally be iron carbide segregating preferentially at grain boundaries. Other constituents, such as oxides, phosphides, and nitrides, probably function in an entirely similar manner, so that the behavior in this respect of ordinary steels, which contain them all, is often quite perplexing. Thus, steels of apparently exactly the same composition and history may differ quite widely in their susceptibility to temper brittleness — and although we can visualize several possible explanations for such conduct, our hypotheses about the real reason still remain almost wholly speculative.

The aging of steel after cold working is also frequently apt to be a troublesome phenomenon. After moderate amounts of cold work, certain steels — perhaps particularly those of the "rimming-in" type — suffer a gradual and progressive alteration in hardness and impact strength and this is even more marked if the steel is held at temperatures slightly above normal — say from 200 to 400° F. This, be it noted, occurs even without previous quenching from high temperature, or other solution treatment.

E. B. Whittemore finds that the hardness of a moderately cold worked mild steel, containing about 0.10% carbon, may increase by 4 to 6 points Rockwell during subsequent aging (about 30 days) at room temperature and above. Boiler steels of the conventional type may suffer progressive diminution of impact strength under similar conditions amounting to from 25 to 60%, accompanied by increases in yield point and tensile strength ranging from 10 to 40%. Now it cannot be so stated with certainty but it appears likely from evidence presented by Whittemore in his 1933 article in *Transactions*, A.S.S.T., page 571 (who states it does not occur in steels having

less than 0.0025% C) and others that this again is due to the precipitation of very small amounts of carbon in some form.

But why, you will ask, should it be caused to precipitate by a little cold work? In a slowly cooled steel whatever carbon is present should be in equilibrium and not susceptible to precipitation! Why should crystalline slip (a mechanical process) bring about precipitation (a chemical process) and a change in the equilibrium conditions?

Possibly the answer may be somewhat like this: We know that solid solubilities are decreased by the lattice distortion occasioned by the introduction of other soluble constituents. We may, I think, reasonably surmise also that the solubility of a metal or constituent in a homogeneous lattice is decreased by the distortion of that lattice irrespective of the means by which it is brought about.

We know also from studies of the behavior of duralumin during room temperature aging that cold working after quenching will accelerate its age hardening (presumably because of the impetus to diffusion given by lattice distortion, in turn caused by the cold work). May it not be reasonable to suppose that the ferrite of unworked steel, although merely saturated with respect to carbon, is through cold work rendered supersaturated, and that it consequently decomposes gradually thereafter at a rate abnormally accelerated by the instability of its distorted lattice?

Blue Brittleness

The aging behavior of steel is probably closely related to the so-called blue brittleness of steel, although the latter may be influenced by other causes as well. Many steels, in quite unorthodox manner, appear to be harder and less ductile at temperatures around 400 to 600° F. than at ordinary temperatures. It has been suggested that the plastic deformation incident to tensile testing itself causes concurrent precipitation of carbides or nitrides and that it is to this precipitation when tested at such mildly elevated temperatures that the blue hardness and blue brittleness are due. Köster has shown in his above-quoted work on nitrogen in steel that nitrides are precipitated quite promptly during aging at temperatures within the blue brittle range after prior cold working, and it seems natural to suppose that this may likewise occur simultaneous with deformation at the aging temperatures. Thus, at "blue brittle" temperatures, precipitation is sufficiently rapid that the apparent strength and hardness are increased simultaneously as the test progresses. We are not able, according to this view, to test the properties of the steel as they really were before deformation, but only as they are developed during and after deformation and structural alteration. Support for this view is given by the fact, as reported by Galibourg in *Revue de Metallurgie*, page 96, 1933, that a property such as true elastic limit, not requiring prior plastic deformation for its determination, is not higher, but lower, in the blue brittle range, even in a steel that shows a higher tensile strength in this range.

Whether or not we are right in classifying the work-aging and blue brittleness of steel in the same category with precipitation hardening, the two phenomena do appear to be closely related to it and in some cases, at least, steels which are found to be substantially free from the first two are free also of the last.

Finally, I want to remind you of the interesting suggestions put forth by H. J. French in his Campbell Memorial Lecture before the New York convention (1933). He observed certain very striking cases where endurance of steel was improved by prior overstressing, and has found them in temper-brittle steels, which we recognize to be susceptible to precipitation of various sorts. Following the ideas advanced to explain "work aging" of steel, he considers the possibility that the plastic deformation incident to overstressing in the fatigue test may have induced some precipitation of carbon or other constituents. He suggests that the fatigue strengthening which results from this overstressing may be due to "work aging." The suggestion seems a very fertile one and its further investigation may well throw some useful light on some of the puzzling things in the field of fatigue of metals.

So much for steel! I have had to rush along rather rapidly in this field, but perhaps I have written enough to convince you, even if I have done nothing else, that steel and age hardening have a lot to do with each other and that from time to time it will probably be quite useful to consider some of the problems of steel in the light of what duralumin has taught us.

As we look back, it appears that while we have sought to discover age hardening possibilities in non-ferrous alloys, we have rather sought to avoid them in steel. Perhaps the future trends in these two closely related fields may be much more harmonious!

THOSE HOPKINS BARS

what happened on night shift

by Adolph O. Schaefer
Secretary
Philadelphia Chapter, A.S.M.

I FOUND JOHN SITTIN' OUT BACK OF THE Annealin' Plant, smokin' one of them nickel cigars like he always does on the tail end of lunch time. On'y this time he was lookin' at a piece of paper with a yellow border an' some little pitchers on it, an' not acrost the tracks to the back of the houses on Peach Street like he usu'lly does.

John's foreman in the Annealin' Plant, an I'm a machinist down in the Roughin' Shop. Our wives is related, an' I usu'lly stops up at John's lunch time to trade the low-down on the family for a minute if I got a straight cut an' can leave my helper with the job.

"Whassa matter with you, are they after you to join a new union, or you thinkin' of buyin' a Lincoln this year?" I says.

"Hell, I'm thinkin' o'bein' a metallurgist like Doc Stokes, an' find out whassa matter with this goddam plant," John says.

"Tha's easy," I says, "When I gets a machinin' job with some of this lousy steel in it, I'll show it to Charlie the Inspector, an' he'll tell the boss, an' you can come down in the Shop with a little bottle of acid an' some cotton, an' I'll tell you whassa trouble. Why don' you take up bein' a mail man or a cop or some job where you can see life?"

John pays no attention to me. He's the best foreman they ever had up in the hill, an' the Company knows it. He didn't lose hardly no time at all in the depression.

"You know this kid Neeley they got up in th' Lab last summer?" he says, "He give it to me." An' he hands me the paper.

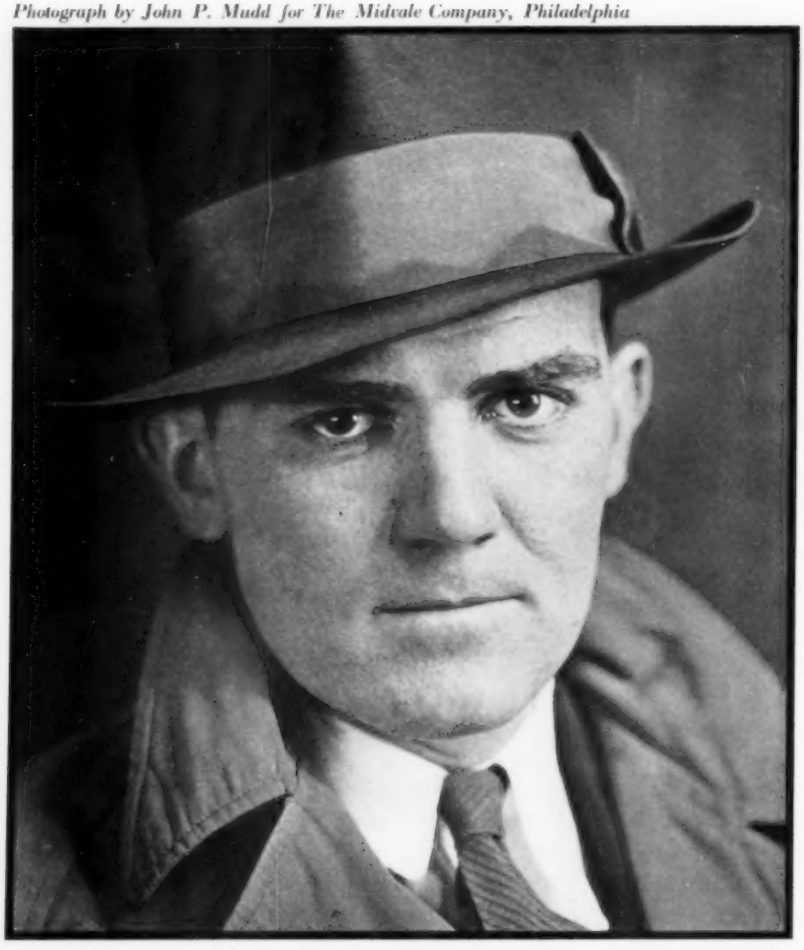
I sees it's a membership blank for some club or somethin', an' I hands it back. "Well they's all kinds of ways of gettin' out nights," I says, "but you got bowlin', an' the Lodge, an' now the Union. The ol' lady'll think she's hitched to a travellin' salesman."

John laughs. "This kid Neeley says I ought to join. He's a nice kid, he don't act smart like th' guy they had last year, an' he comes up here an' eats his lunch with me sometimes, an' tells me about what they learned in college. I bin showin' him things about runnin' furnaces, an' he's bin showin' me some o' the tests they're gettin' out lately.

"You know th' steel business ain't what it used to be. When I started heatin' up here, ol' Jim Ferguson was boss, an' they was on'y four or five kinds o' steel to run. They was tool steel, an' high speed come along later. They was machinery steel, an' nickel steel, an' tha's about all. Course we didn' handle some o' the special stuff like they do over in th' New Treatment Plant, but they was th' chief products.

"Nowadays you got a dozen kinds o' tool steel, an' a lot more o' them alloys that started

Photograph by John P. Mudd for The Midvale Company, Philadelphia



"Neeley Was Set to Follow th' Job in Case Anythin' Comes up."

with nickel, an' then got to chrome nickel, an' now they got everythin' in 'em but the kitchen sink. Then along come stainless, an' now they're goin' nuts over grain size or somethin' else.

"Anyway Neeley tells me when th' tests are goin' good, an' when they runs into trouble, an' when they gotta scrap th' stuff; an' anyway I likes th' kid 'cause he ain't too smart.

"Las' week we was runnin' a lot o' bars for this Hopkins Company that makes so much stuff for automobiles. Neeley told me about it 'fore it come up. It was somethin' bran' new, we'd had bars with just as much nickel, an' just as much molly in before; but they'd been foolin' down at the a-lectric furnace to make this stuff better somehow.

"Hopkins buys a lot o' steel, but they ain' bought much from us, so Neeley was tellin' me they was anxious to give 'em somethin' just right.

"Well anyway, Doc Stokes an' they had figured out the treatment that was just what these bars needed to suit Hopkins, an' Neeley was set to followin' the job.

"An' mebbe they hadn't laid out *some* treatment. They had to be heated up pretty hot, an' then spread out to cool, all just th' same, an' then that had to be done all over again. Then they got a low heat, an' they had to be held there a long time. Even th' coolin' was fancy — so many millivolts an hour to say eight hunderd an' held there, then picked up to say a thousan' an' held there, and then cooled so many millivolts an hour again. I forget all th' stuff they had writ on the ticket, but I like to see one o' them guys try to hold one o' them old oil furnaces at any temperature below a thousan'.

"Anyway we had to do it, an' Neeley was set to follow th' job in case anythin' comes up. Dam if th' kid don' stay right there all the firs' night, an' on the second day. They got 'em cooled twice all right in the air like they was supposed to' an' he seen 'em do it.

"Second day his tail was beginnin' to drag, an' I was worried he'd stay all night again. Anyway I talked to 'im, an' told 'im I'd come up tonight an' telephone 'im if anythin' was wrong. He didn't want to go, but I showed him where we'd still be at it tomorrow, an' he seen he'd better get some sleep.

"Tell the truth I was comin' down that night anyway. Sam McGee's hours was up for th' week, an' I had to put Shorty on heatin' Number Seven and Eight because he's a on'y man I got left. Shorty's all right on an ord'nary job, but th' kid had me worked up by this time, an' I wanted to see that they followed th' ticket right through.

"Well I guess you heard the wife beefin' about me bein' out all night las' Sunday when you was up with th' missus. I didn't turn in no time f'r myself, so I didn' get no pay, an' you can't explain anythin' like that to wimmin. An' I been itchin' to tell somebody what went on that night, an' it might jus' as well be you, 'cause you won' know what I'm talkin' about, an' if you

open your mouth to anybody else I'll bring home th' story o' that smoker you went to las' month, an' your wife'd be glad to hear about the kin' o' night work you been doin'.

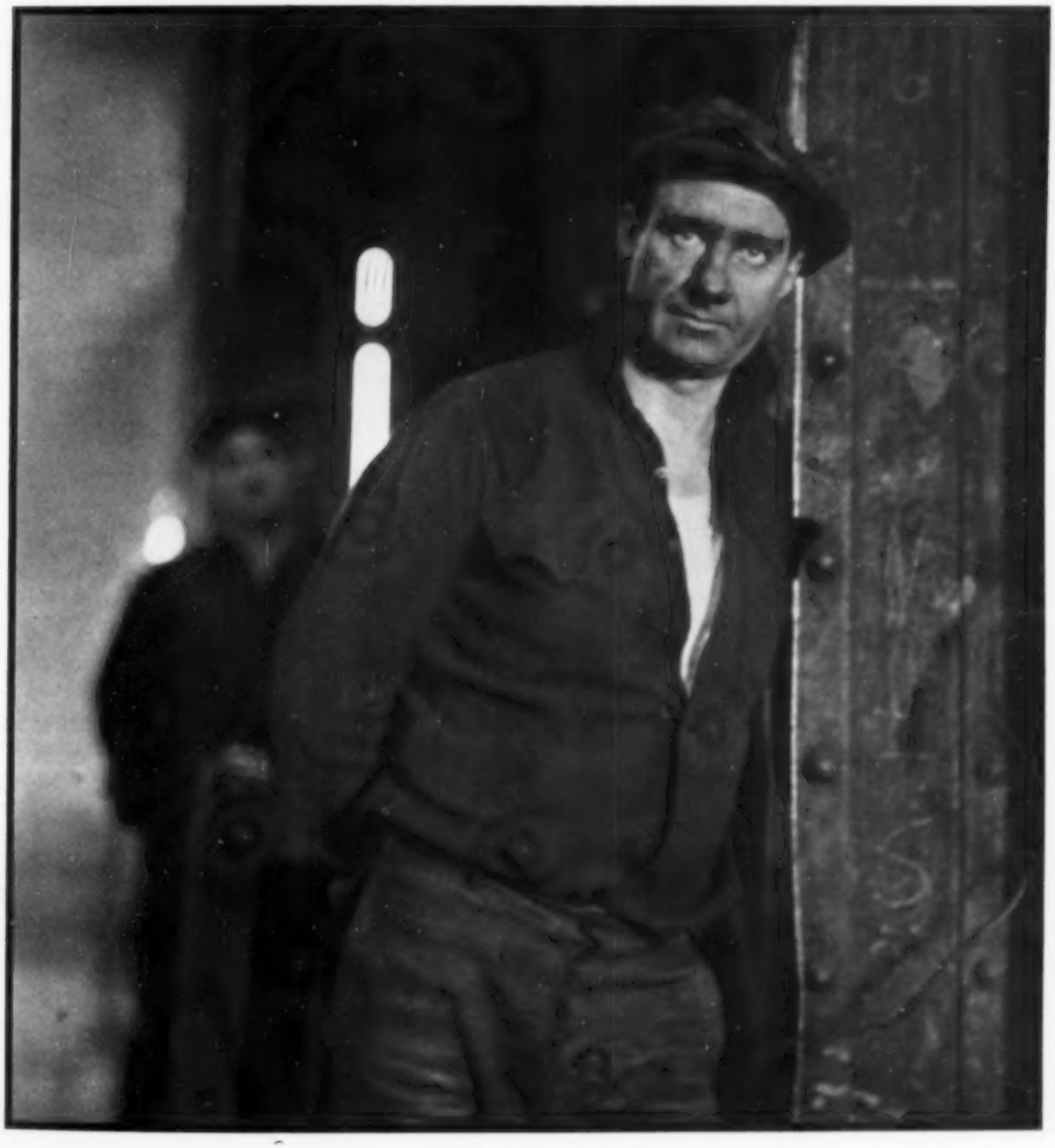
"These Hopkins bars is pretty long, see, an' I got 'em in Number Seven, an' they were goin' along fine on the long hold 'long about twelve o'clock when Shorty come on. I was beginnin' to think I'm a goddam fool to be hangin' aroun', an mebbe Shorty's all right, an' I might o' been gettin' a good night's rest like th' kid, when all of a sudden things begin to happen.

"Number Seven was runnin' a nice heat, an' Shorty's been out at the wrestlin' matches, an' was tellin' me why he thinks Ernie Dusek ought'a be champeen, when she started sputterin', an' first thing I know we couldn't get no oil, an' we couldn't keep th' burners lit, an' we figgered right away th' oil line's clogged. Well I lit out for th' office, an' got hol' o' the Engineers right away. Like it al'ays is when you want 'em, they was all hands fixin' a leak over in th' Boiler House, an' it would be three or four hours till they could get up to us.

"Well mebbe I ought 'o kep' my head, an' let 'em go for a few hours till the Engineers fixed us up; but I couldn' help thinkin' o' the kid, an' how fussy he was about this heat, an' I kind'o felt it was up to me 'cause I'd sent 'im home. An' my firs' idea was all right if we ain't had more trouble. But I figgered this way. It was on'y the South end of the Shop tha's on the old pump that wasn't gettin' oil. Everything was O.K. in the North end. An' they was so fussy about how many millivolts an hour they cooled, so I figgered we'd better do somethin'.

"Number Four was jus' comin' up with a lot-a machinery steel that was in for a ord'nary

"John's the Best Foreman They Ever Had, an' the Company Knows it; He Didn't Lose Hardly no Time at All in the Depression."



J. P. Mudd for The Midvale Company

Photograph by John P. Mudd for The Midvale Company, Philadelphia

"I Felt Kind o' Funny Tellin' Shorty That Both Clocks Better Break Down Right Away, But Shorty Got It Fast Without Explainin' "

anneal, so I thinks why not make a quick shift, an' nobody's gonna know the difference. So I tells Shorty we gotta be quick, an' we yanks th' stuff out o' Number Four. I climbs up in th' crane, an' Shorty does th' riggin', an' we picks up th' Hopkins stuff.

"Well, I ain' blamin' Shorty none. After all, he ain' no rigger an' I ain' no craneman, an' we was hurryin', an' anyway while I'm liftin' 'em over the oil tank, one o' the slings slipped, an' the bars dropped out like a lot-a jack straws. One end of half-a the bars went in the oil, an' then we was in a hell of a fix.

"I don' know whether I did any thinkin', but we had plenty of action. Right away I figgered these bars had to be uniform, so I drops th' whole load in th' oil, so they all got th' same thing. Then I came down out o' the crane to try to think what to do next.

"I been foreman a long time now, but tha's the worst spot I ever been on. I was even too worried to ball out Shorty, an' he was expectin' it. Tell the truth I was damn near sick at my stummick. I ain' chewed none since the girl growed up, an' gimme her ideas on th' subjick, but this time I borrows a chew off Shorty an' sits down onna edge o' the tank.

"'Shorty,' I says, 'if anybody else a-done

that I'd o' had his walkin' papers made out if he was th' best goddam heater in th' place.'

"Shorty says, 'Well the boss'll be makin' out both our tickets tomorrow when he sees this mess. How you gonna tell 'im why you put 'em inna tank? If I'd known you wuz goin' to do any tricks like this, I'd 'a had a few shots onna way in so's I could have a good time too.'

"I'd been thinkin' while Shorty was talkin', an' by the time he was through I had a idea.

"'Shorty,' I says, 'We gotta fix this thing up.' So I told 'im about Neeley, an' how important these Hopkins bars was, an' we got out the tickets, an' looked at what they was supposed to get.

"Well I figgered these bars had been cooled out in th' air from forty-six millivolts the last time they was cooled. If we spread 'em out on th' floor o' Number Four an' fired hell out o'her, we could get 'em up to forty-six in a coupla hours. They was on'y one inch bars, so if we left 'em soak a half hour anyway, they oughta be all right. Then we could spread 'em out on the skids an' let 'em cool for a coupla hours. It was pretty cold, an' I figgered the color'd be out of 'em then. Then we could fire 'em again fast to that last low heat, shut off th' oil, an' they'd cool in a coupla hours to where they'd ought-a been if we hadn't had the accident.

"My idea was that then they'd have as near the treatment they should o' had in th' time we had left to give it to 'em, which was by eight o'clock inna mornin' when Neeley was likely to come in. I knew th' boss wouldn' be in till nine, an' if we could fix the clocks nobody'd know the diff'rence, except that we'd had to switch furnaces in a hell of a hurry, an' we could swear they was at th' same temperatures an' we'd done it fast.

"I felt kind o' funny tellin' Shorty that both clocks better break down right away, but Shorty got it fast an' I didn' have to explain.

"Well in all th' years I been takin' this Company's money, I never put in such a night. We worked like hell, an' sweat was runnin' off us both most o' the time. Shorty can take it though. First of all it was my bull, but he didn' say nothin', jus' worked, an' we got them bars treated 'bout as fast as any I ever see.

"We had to call in the electricians to fix th' clocks, an' when McNally came aroun' in the mornin' to fix 'em, the bars was just about where they'd ought-a been if we'd been lettin' em cool right accordin' to the ticket. McNally come aroun' after he'd fixed the clocks, an' gimme a fishy look in the eye.

"'You been here all night?' he asked.

"'Damn right,' I says, 'I wouldn' leave these Hopkins bars alone with nobody. What the hell's 'a matter with you, you don' have to pay me out o' your pocket?'

"'Nothin', McNally says, 'but if you wasn't, I'd say they was somethin' funny 'bout the way them clocks was busted.'

"'There's nothin' funny about me workin' twenty-four hours, an' havin' a clogged oil line, an' two busted clocks, is they?' I wants to know, an' McNally thinks he better shut up.

"So Shorty goes home, an' the day gang comes on, an' Neeley comes in lookin' fresh as a daisy an' all excited because he was ten minutes late.

"'How are they?' he says first he seen me.

"'I been settin' here holdin' their hand all night, an' I ain' noticed nothin' wrong,' I says.

"Well it took a little arguin' to show him that we had shifted furnaces quick, an' on'y when we had to, an' that Number Four was a little hotter than Number Seven when we put 'em in.

"Las' thing Neeley says was, 'Gee, I wish I'd o' been here to take care of 'em.'

"'Boy,' I says, 'Shorty an' me has wet nursed them bars all night like we was their own mother. I'm sure we done everythin' we could do for 'em.' Course he never knew that was a wise crack."

John got up and stretched, an' lit his cigar again. "Looks like we're gettin' new neighbors," he says, an' points over to Peach Street where another shine family is movin' in.

"Well, when are you goin' to get fired, an' how did them bars turn out?" I wants to know.

"Tha's what makes me think I ought-a join this club," he says, pointin' to the sheet o' paper he'd been readin'. "Them bars passed all the tests here at the Works. They was shipped two weeks ago, an' just this mornin' Neeley brings a letter from Hopkins down to show me. They say them bars was just like they want, an' th' best lot they had for a long time."

"You al'ays was the luckiest bum in the family. If I'd of pulled a stunt like that I'd be standin' in line at the next shop down the street."

John was laughin'. "You know what Neeley says when he hands me this?" he asks. "He says I had a lot o' practical experience, an' I ought-a come down to these meetings to learn th' reasons in back o' laying out a heat treatment. He says then I'd know why it was so important that them Hopkins bars should get th' exact heat treatment that had been laid out for 'em by old Doc Stokes."

NEW HIGH SPEED STEEL

molybdenum

with tungsten

by Frank Garratt
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Technical Director
Universal Steel Co.
Bridgeville, Pa.

METALLURGISTS DEALING WITH TOOL STEEL have been experimenting with molybdenum as an alloying element for at least 50 years. For 30 of them the metal was scarcer and more expensive than its chemical cousin tungsten, but since the development of deposits in the Rocky Mountains, this handicap has vanished. In fact, the post-War efforts to make this country self-sufficient in strategic materials have led to extensive work at Watertown Arsenal and elsewhere on molybdenum high speed steels containing no tungsten whatever.

Nevertheless, these high molybdenum steels have not, until quite recently, established themselves firmly in the American market. There are several explanations for this retarded development and it is likely that had molybdenum been available in greater quantities, and more modern methods of investigation been available to the early workers, the position of molybdenum in high speed steel metallurgy would have been dominant.

Any serious consideration of high speed steel must start with the monumental work of Frederick W. Taylor and his associates at the turn of the century. In addition to tungsten steels they also investigated molybdenum steels and clearly showed that approximately one part of molybdenum was equivalent to two parts of tungsten in producing a steel having high speed properties. Tools having this relationship (and otherwise similar in composition) were found to have approximately the same cutting properties.

Several manufacturers, both here and abroad, did considerable work prior to the War on molybdenum high speed steels. Thus, the recently published "Alloys of Iron and Molybdenum" tabulates analyses of 86 such tool steels appearing in the literature between 1902 and 1931. They fall into three principal groups. Many of them have high tungsten (12% and more) and only a little molybdenum apparently intended to fortify the effect of the other element. The second class has about equal amounts of the two elements, while the third has eliminated all tungsten in favor of molybdenum. Apparently no one had considered the possibility of an analysis where molybdenum is present in quantity 3 to 4 times the tungsten — the basis of the present successful analysis.

The material described in this article is the result of efforts to produce a more economical high speed steel without sacrificing cutting qualities in any particular. The work was undertaken in cooperation with the Cyclops Steel Co., and the initial efforts were directed towards the production of an economical substitute for hacksaw blades. Molybdenum compositions were particularly attractive because of their lower materials cost, and their lower densities, the steel finally perfected having only 91% of the weight of regular tungsten high speed steel.

Early in our experiments with molybdenum we appreciated the necessity for producing

regularly a high quality of product, and much of our work was to perfect a mill practice that would meet the specifications of standard 18-4-1 high speed steel (18% tungsten, 4% chromium, 1% vanadium).

As the result of supplementary investigations it was found that the inclusion of tungsten, in somewhat definite relation to the molybdenum, resulted in more uniform material and most of the work has been confined to a molybdenum-tungsten steel. A chemical analysis of a typical specimen will show the following: Carbon 0.76%, manganese 0.30%, silicon 0.30%, tungsten 1.60%, molybdenum 7.90%, chromium 3.85% and vanadium 1.10%. It has been marketed for some time under the trade name "MoTung."

Material of a similar type was independently developed by J. V. Emmons of the Cleveland Twist Drill Co. and was described by him before the American Society for Steel Treating at the Buffalo meeting in October, 1932. Emmons' experiments dated further back than the writer's, and patents were issued to him covering a broad range of compositions. Material covered by the Emmons' patents has been given the general type name "MoMax."

Most investigators have been so engrossed with bettering the 18-4-1 class of high speed steels that they have paid little attention to simpler compositions, such as are represented by these molybdenum-tungsten types. Many modifications of the typical 18-4-1 have been offered; they usually have increased percentages of carbon, tungsten, and vanadium; in some cases substantial additions of cobalt are made. Molybdenum is frequently present in minor amounts and the chromium may be higher than the usual 4%. For certain classes of work, these so-called super high speed steels have given very good results, but all their properties have not been entirely satisfactory. Therefore the 18% tungsten, 4% chromium, 1% vanadium analysis represents by far the largest amount of high speed steel produced today, most users having concluded that the extra service derived from "super high speed" in any ordinary application is not worth the premium.

As before noted, the Universal Steel Co. has given much attention to mill practice on these molybdenum-tungsten tool steels, achieving consistently uniform results which remove the oft-heard objection that molybdenum high speed steels are quite variable in response to heat treatment and in cutting performance. In fact, the new analyses have proved to be quite tough at forging and rolling temperatures. Twelve-inch ingots can be handled in a blooming mill, the metal being not so stiff as 18-4-1, which is usually cogged down under a hammer. While the molybdenum-tungsten steel may not be heated as high, it is workable through as wide a temperature range, so rolling to bar or strip is readily done. Its machinability in the fully annealed condition (Brinell 228 max.) is also definitely better than 18-4-1.

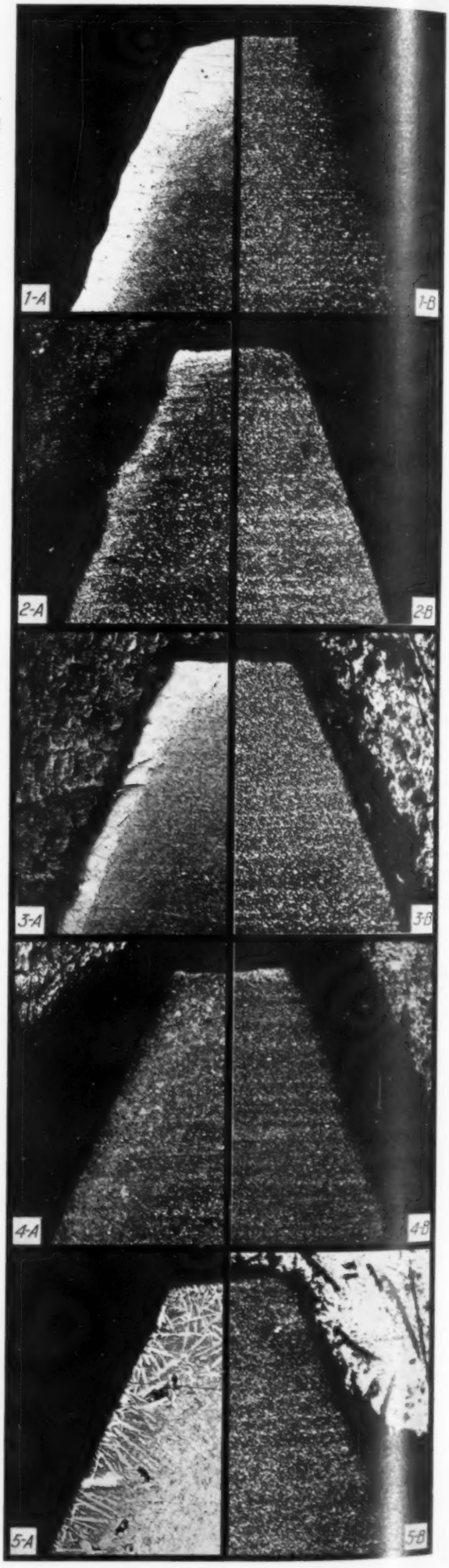
It will be found that steels of the type being discussed forge more readily than tungsten high speed steels and lower forging temperatures are advisable. Before discussing actual temperatures, however, a word should be said about surface protection. When the material is heated in open air, oxidation of the surface naturally results in the formation of oxides of iron, molybdenum, and carbon. The common oxide of molybdic acid (MoO_3) is volatile at steel working temperatures, and forms a voluminous white vapor familiar to all who have worked with high alloys of molybdenum. The amount of this smoke is deceiving, however, and has led many to assume that nothing much else was happening, whereas investigators at the Watertown Arsenal have proved that the "soft skin" resulting from heating in open air is due more to loss of carbon than molybdenum.

Excessively oxidizing atmospheres should naturally be avoided as well as abnormally long soaking periods at forging temperatures. The use of temperatures higher than actually necessary is also a disadvantage. When using these precautions ordinary machining allowances will usually remove any resulting soft skin, but if unusual precautions are necessary, borax is an excellent protector.

When borax in powder form is thrown on heated steel it melts rapidly and quickly forms a thin film. Borax may be added in several ways, the simplest for occasional pieces being to sprinkle the powder on the heated steel, or roll the mildly heated pieces in a borax box, shake off excess, and return them to the furnace to complete the heating. Borax may also be applied by a saturated water solution at 150° to 200° F. Parts previously heated slightly above the boiling point of water are immersed in it momentarily, and evaporation leaves a fine incrustation of borax. It is rather remarkable what a small amount of borax is necessary. Merely painting the steel with hot, saturated borax solution is sufficient.

General precautions for forging are the same

Views of Screw Threads at 100 Diameters (After Mounting in Soft Material to Preserve Edge During Polishing) Showing Effect of Various Atmospheres on Surface. See table at top p. 41 for details. Specimens in right column were protected by thin film of borax



as those observed for tungsten high speed steel, although lower temperatures should be used. It is advisable to heat slowly in the early stages. Temperatures should not go beyond 2050° F. — 1975 to 2025° F. will be correct for most purposes, and the steel can be worked down to 1600° F. Then cool slowly, and anneal by usual methods at about 1500° F.

As in the case of 18-4-1 high speed steel, close control of heat treatment is necessary to develop maximum potentialities. When such control is exercised, molybdenum-tungsten high speed tools give performances fully the equal of the standard 18-4-1, and for some applications definitely better results are obtained. It is probable that if, by some miracle, all the 18-4-1 tools in this country were replaced overnight by the new high speed, nine out of ten of the machinists would never know the difference unless they noted a changed appearance in the spark when grinding the tools.

Heat treatment of the two steels is quite similar in principle, the only variations being in the temperatures employed. Preheating is done at 1250 to 1450° F., the lower temperature being preferred to minimize decarburization.

Fully hardened tools are obtained by cooling from 2150 to 2225° F., the exact temperature employed being dependent on many controllable factors. Maximum performance and greatest uniformity are obtained through proper atmospheric control in the hardening furnace. Soft skin can be entirely prevented by heating in proper salt baths, which are ideal for hardening purposes. The comparatively low hardening temperatures are a distinct advantage to such baths. Muffles of carbonaceous material have also given good results.

The heat treatment of this type of steel presents no difficulties to the organization familiar with up-to-date methods. In other words, we advocate modern hardening technique for a modern alloy tool steel.

Considerable work has been done on the heat treatment of molybdenum-tungsten high speed steel in fully enclosed muffles heated either with electricity, or gaseous or liquid fuels. If an atmosphere of proper composition is employed, many tools can be treated practically free from

Effect of Atmosphere and Borax on Soft Skin

Gases in Atmosphere		No Borax		Borax Dip	
CO_2	O_2	Thickness of Skin	Micro	Thickness of Skin	Micro
2.0%	18.0%	0.0125 in.	1-A	0.0025 in.	1-B
11.6	—	0.0075	2-A	0.0005	2-B
2.2	—	0.0130	3-A	0.0002	3-B
2.0	—	0.0040	4-A	0.0005	4-B
0.0	—	0.0005 (Carburized)	5-A	0.0005	5-B

soft skin. Results obtained depend a great deal on the type of tool; tools free from projecting parts are easier to treat entirely free from soft skin than those having sharp projections, such as hacksaws and taps. Projecting points are a prey to adverse atmosphere and the extreme tip of the thread (in the case of threading tools) may be soft while the balance of the tool has a satisfactory surface.

Furnace atmospheres containing a minimum of 5% carbon monoxide, not over 3% carbon dioxide, and reasonably free of water vapor minimize soft skin except in tools having very sharp cutting edges. In attempts to eliminate entirely this difficulty, it was found that merely dipping tools into borax solutions was quite effective. This method of producing a protective film of borax has been described above; the barely warm tool should be dipped in the solution, then preheated, and then transferred to the high heat furnace. The latter should have controlled atmosphere — readily formed in a separate unit by partial combustion of the fuel gas, and the moisture removed by suitable drying reagents. A "seal" in the form of a supplementary flame at the mouth of the furnace protects the contents from an inrush of oxygen when the door is open.

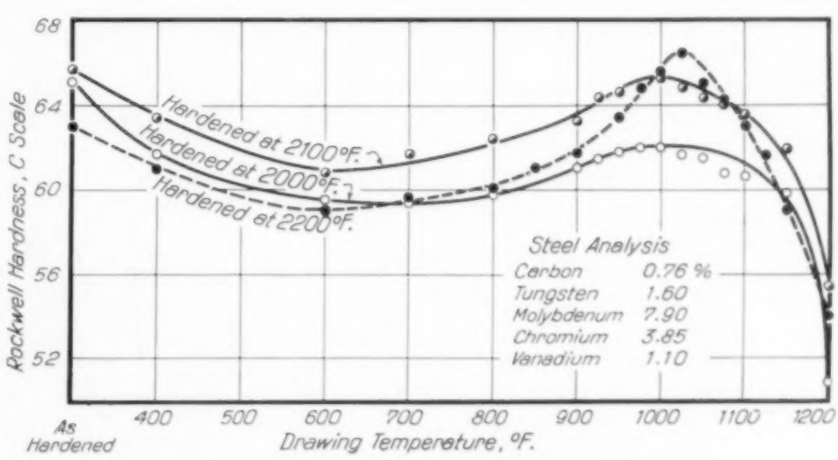
Some tests with molybdenum-tungsten steel in such equipment will be informative.

In order to accentuate the decarburization, ½-in. bars, 3 in. long, were cut with a standard U.S. screw thread, heated to 500° F. before immersing in the strong borax solution. Preheating furnace was maintained at 1250° F.; its atmosphere was of an oxidizing nature. After being thoroughly preheated the specimens were heated for a sufficient length of time in the high heat furnace. Atmosphere in the latter was varied as to carbon monoxide content (by varying the ratio of hydrocarbon gas and air entering the system). A fan distributed the atmosphere throughout the hardening furnace.

After quenching and tempering, the soft skin was removed by a good test file and depth measured by loss in diameter of the threads. The accompanying table and associated microsections at 100 diameters give the results.

Under the conditions prevailing during these tests, a slight haze occurred in the hardening chamber at 14% CO, and when this was increased to 18% it was definitely smoky. It will be observed that atmospheres containing around 10% CO decarburize a specimen unprotected with borax more than leaner atmospheres, and our observations indicate that the action is also somewhat different in nature. The extreme surface, as shown in micro 3-A (and more effectively shown at higher magnifications) is free of carbides, and under this is a region of partial decarburization, soft to the file. This condition is corrected as the carbon monoxide content increases and around 18% CO the atmosphere contains considerable free carbon and unburnt hydrocarbons and these constituents are undoubtedly important factors in the carburizing action noted in micro 5-A.

The table shows that the slight film of borax is very effective in preventing decarburization in lean atmospheres, as well as carburization in rich ones. Atmospheres containing 5% carbon monoxide, or more, have practically no effect on the surface characteristics of the specimens when

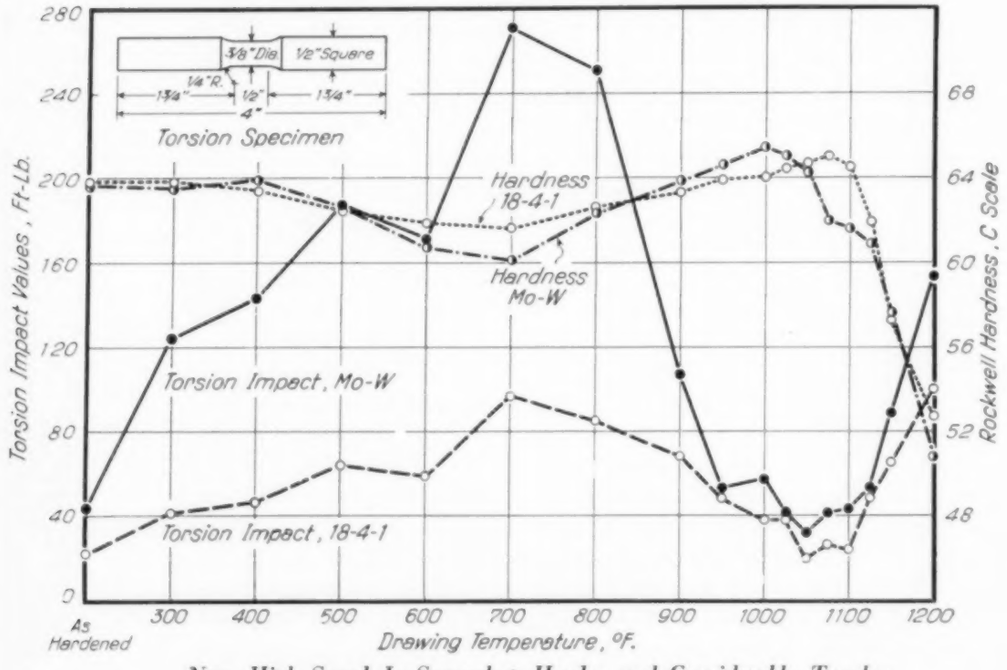


Effect of Drawing Temperature on Molybdenum-Tungsten High Speed Steel, Quenched From Various Temperatures

tested with a file, and this has been confirmed by microscopic examination.

Hardening of commercial tools has confirmed that the method is quite practical, and offers a scheme for hardening molybdenum high speed steels practically free from soft skin.

Many heat treating plants do not have controlled atmosphere furnaces. Where the existing equipment consists of an open type of furnace wherein the products of combustion mix with the atmosphere surrounding the tool, it is advisable to use powdered borax, as described fully above.



New High Speed Is Somewhat Harder and Considerably Tougher Than Standard 18-4-1 High Speed. Quenched from 2190° F. and 2375° F. respectively, to austenite of similar grain size, then drawn

Hardened tools are tempered the same as regular tungsten high speed steels, the only difference being in the use of slightly lower temperatures. Maximum secondary hardness is developed by reheating to 1000 to 1040° F., depending somewhat on the hardening temperatures and conditions, and type of tools.

If the hardness is plotted against the drawing temperature the shape of the curve is similar to one plotted for 18-4-1 steels, the exception being a lower hardness at about 600° draws and recovery to slightly higher values at the point of maximum secondary hardness. The diagram on page 41 shows values obtained when tempering ½-in. square sections which have been hardened at various temperatures.

Early experiences indicated that the new material is definitely tougher in the hardened and tempered condition than tools of the 18-4-1 type. Torsion-impact tests have emphasized this difference, as will be noted from the set of curves on this page. Points shown are the averages of three determinations made on the specimen sketched.

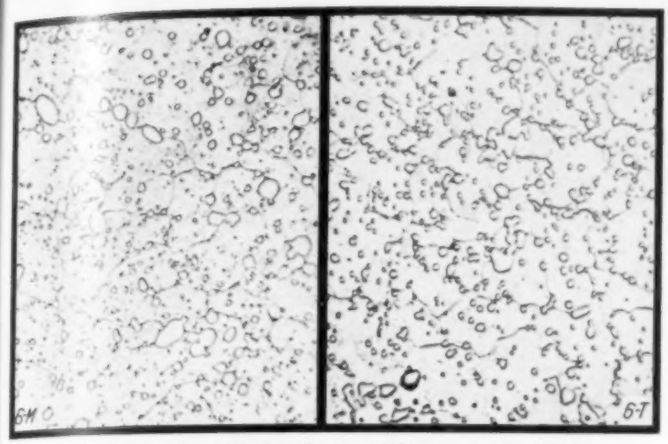
In these experiments the "MoTung" specimens were hardened at 2190° F. in an atmosphere containing 10% carbon monoxide, while the 18-4-1 specimens were hardened in a similar atmosphere at 2375° F. Holding time at hardening temperature was adjusted to produce the same type of microstructure in each grade. Micros 8-M and 8-T show the type of martensite developed after tempering to produce maximum hardness. All specimens were rough machined to 0.390 in. diameter, and then heat treated, finish ground to 0.375 in. diameter, and tested.

Values in excess of 120 ft-lb. were obtained with more than one blow of the falling hammer, and in such cases the cumulative values of the added blows were recorded as the torsion impact values. This method of recording may be criticized by some, but it should be emphasized that the difference in values obtained is wide enough to indicate the greater toughness of the molybdenum-tungsten steel at all drawing temperatures.

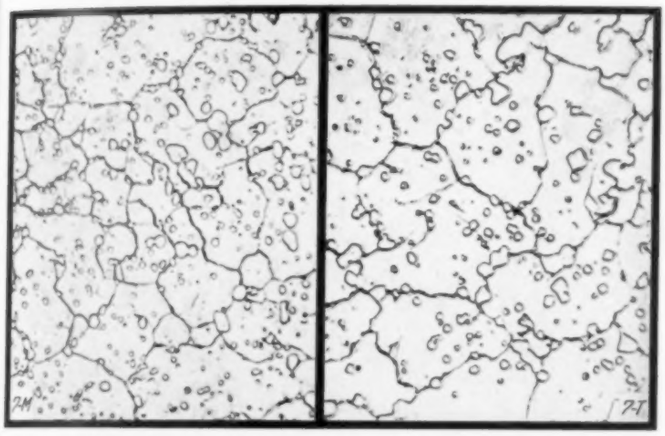
Metallographic constituents in molybdenum-tungsten steels, as marked M on the next page, are quite similar to those found in 18-4-1 high speed steels (companion micros marked T) although there are fewer massive carbides and those which do exist are smaller in size.

The characteristic polyhedral constituent, customarily referred to as austenite, is found in samples rapidly cooled from 2000 to 2050° F. Long holding time at 2000° F. will produce very definite austenite outlines in the etched surface, while if the holding time at this temperature is short, grain boundaries may not be detected.

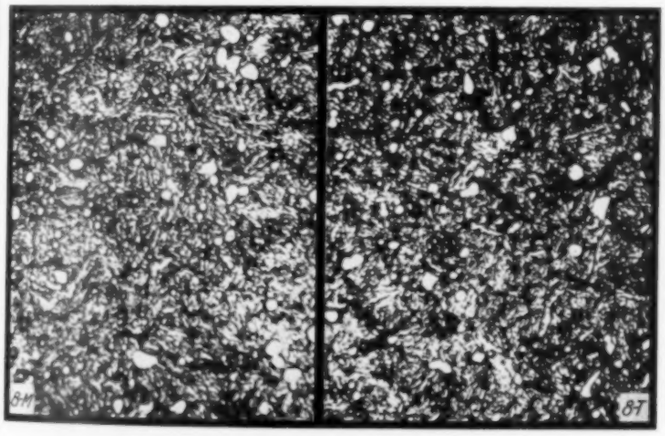
The size of the austenite grain, and the char-



"Underhardened" Specimens (Untempered) With Fine Austenitic Grain, Rather Poorly Developed



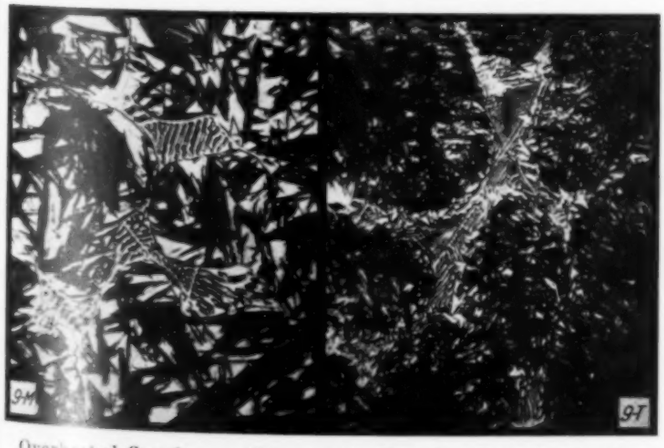
Properly Hardened Specimens (Untempered)



Heat Treated to Maximum Hardness

Quenched from 2190° F. Tempered at 1000° F.

Quenched from 2375° F. Tempered at 1075° F.



Overheated Specimens (Tempered) Showing Eutectic Patches

Comparison of Microstructures at 1000 Diameters of Molybdenum-Tungsten and Standard 18-4-1 Tungsten High Speed Steels, "M" and "T" Respectively

acter of the free carbides, give an indication of the effectiveness of the heat treatment. Low hardening temperatures produce rather indistinct and small grain size (micros 6-M and 6-T), while higher temperatures produce coarser austenite. If heating is carried to extremes, coalescence of the free carbides occurs, and dangerously overheating the material results in the formation of the austenite-carbide eutectic in the cooled sample. The material behaves no differently in this respect than the usual 18-4-1 tungsten high speed steels — see photomicrographs 9-M and 9-T.

Tempered samples exhibit a martensitic condition quite similar to tungsten high speed steels. Martensite precipitated from fine grained austenite is fine and rather indistinct, while coarse grained austenite yields martensite of the more coarsely acicular type.

While the "underhardened" microstructure shown in 6-M would not represent satisfactory hardening for most types of cutting tools, it would be better to produce it and draw at rather lower temperatures for certain tools where toughness is the essential property (as for wood working bits and certain types of punches). It is well to emphasize, therefore, that there is no general heat treatment that will produce the best tool for every purpose.

Considerable work has been done on the properties of types that are modifications of the base composition. The modifications studied have included varying relations of carbon and vanadium up to 1½% and 3% respectively; additions of nickel up to 2½% with varying percentages of carbon and vanadium; additions of cobalt up to 12% with varying percentages of carbon and vanadium; and increased percentages of tungsten, molybdenum, and chromium.

As a general statement it may be said that the base composition offers maximum cutting performance per unit of cost. Any change in composition, designed to increase cutting performance, naturally increases the cost of the steel, and it is worth while noting that the composition discussed in this article bears about the same relation to "super MoTung steels" as common 18-4-1 tungsten steel bears to the usual super high speed steels. It is not within the province of this paper to discuss these modifications in detail, for much research work is now being conducted on this phase of the problem.

Radiograph, Somewhat Reduced, of Pot Bottom Showing Various Types of Defects. Major defects were not suspected from appearance of casting, but were easily located and chiseled open. If photograph of the pot, on right hand page, is rotated slightly in the mind's eye, many surface irregularities match exactly with markings on film

INTERIOR DEFECTS

revealed

by X-ray

by F. K. Ziegler
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IT IS SAID THAT UPON ROENTGEN'S ANNOUNCEMENT of his discovery of the X-ray, a well-known professor of physics at a leading university stated that the X-ray was an impossibility, and proved his statement mathematically! In the light of developments since that time, it can only be said that his figures — like many others now quoted — were misleading. It would be difficult to find many persons who do not know of the vast amount of medical and dental information obtained by the use of this same X-ray, because they have come in contact with its wonders, either personally or through a friend or relative.

Basically, the principles involved in X-ray inspection of metals are, of course, the same as those applying to the diagnosis of ills of the human body, yet today there is to be found, even among engineers and metallurgists, some scepticism about the praticability of inspecting high alloy castings in this way. There is a lingering suspicion that there may be defects that are not shown on the film. A few days' actual experience in the foundry inspection department would, I believe, convince these doubting Thomases of the highly practical value of X-ray testing. It is hoped that the accompanying pictures will accomplish the same purpose. In them are illustrated a few of several instances where a casting was broken open to prove the presence of indicated defects — and, contrarywise, the presence of sound metal where the film was clear of tell-tale markings.

The effectiveness of any method of inspection depends upon the accuracy obtainable and upon the facility with which results can be duplicated day by day. The human element is present in all forms of inspection and must always be taken into account; yet its bad effects can be minimized by the use of high grade equipment and intelligent supervision. In no branch of inspection known to the writer is sound judgment and extensive experience more likely to misinterpret outer signs than in the visual examination of a casting. The X-ray literally enables one to look below the surface, and it is then only a question of interpreting the shadows of interior

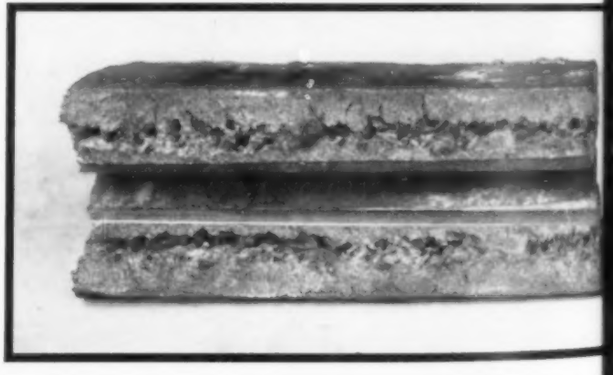
Cylinder Shown Above Looked Like a First Class Casting When It Left the Cleaning Room. X-ray film was laid along a corrugation (as marked with chalk) and the exposure below revealed extensive porosity in one direction only. The end of the cylinder was then broken off and holes were revealed at the expected place (view at lower left) bordered by sound metal. The full length of the defect was exposed by notching above the cloudy line on the film and breaking

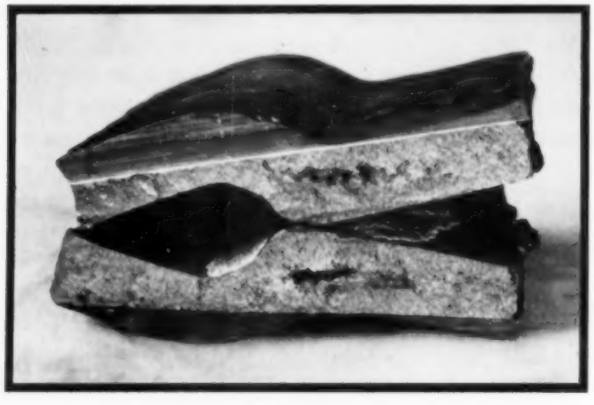
— the first two, respectively 1 and 2% of the thickness, only faintly, but the groove 3% deep and those deeper are plainly visible even on the reproduction.

The shrinkage cavities which are shown, although not visible or indicated on the machined surface by any sign, were found by X-rays before the plate was machined; this particular plate was used to determine whether the rays would show both the shrinkage and the sharp grooves, as well as to prove the sensitivity of the method of inspection. The difference in density of the shadow lines where they cross the flaws can readily be seen, and is due, of course, to the more ready penetration of the rays through the lesser amount of metal above the shrinkage cavities. (This and the other reproductions are "negative prints" from the film, and show black and white

irregularities. Some common examples were given in METAL PROGRESS last December.

The sensitivity of the X-ray in showing differences in thickness of a nickel-chromium casting is well illustrated in the cut on page 47. This is a radiograph of a plate ⅜ in. thick, machined flat on both sides. A series of fine grooves measuring in depth approximately 1 to 6% of the thickness of the plate, were then cut on one surface. All six lines are visible on the radiograph



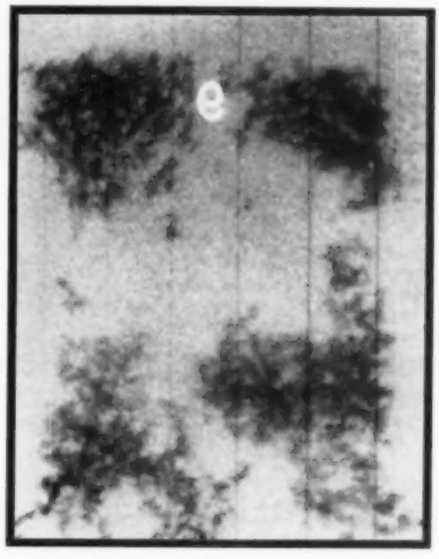


contrasts in the same relation they hold on that film — in other words, denser and thicker portions are lighter, voids and spongy metal are dark. A considerable degree of contrast is unfortunately lost in making the negative print and the engraving therefrom.)

Shrinkage and blowholes, which comprise the major number of casting defects, cause actual differences in metallic section at the point of occurrence. The same effect is produced on the film by solid sand and slag inclusions, even

though there is no void, due to the more rapid penetration of the rays through these solid, non-metallic particles. It is evident, therefore, that the degree of accuracy in locating flaws can be measured by the difference of density of exposure registered on the film.

Considerable doubt has been expressed of the practicability of thoroughly X-raying castings of intricate shape and of widely varying cross-section. Naturally there are, in daily production, castings of such shape that a complete X-ray inspection presents serious difficulties; yet there are really none of good design which cannot be completely covered by the use of a sufficient number of exposures. Unequal sections in an area covered by one film can be made to appear the same by shielding, blocking off thin sections for a part of the exposure, and by other methods known to the technologist. That portion of a curved section capable of being shown on one film is determined by the radius of curvature and the size of the film used. Naturally uniform penetration is impossible if one part of the cassette touched the casting and another part were 8 or 10 in. away. This is not due to the air space between casting and film, but to the fact that part of the rays travel directly through the section of metal at nearly a right angle to the surface, while another portion will travel through a greater thickness of metal on the curved side of the casting with resultant under-exposure or non-exposure of the film. Proper shielding of the film is then necessary.



Sensitivity of X-Ray Inspection Shown by Six Narrow Grooves on 3/8-In. Plate. From 0.005 to 0.025 In. Deep by Equal Increments. Cut is about half natural size

Many of these intricately shaped castings can be X-rayed by the use of small pieces of film in a light-proof paper envelope, dispensing with the use of screens which cannot be bent. The objection to this method is that it results in considerable wear and tear on the tube, since the exposure time (without proper intensifying screens) is considerably increased. The alternative to spending too much time and money on the inspection of intricate castings is the taking of radiographs at certain spots where experience has shown that defects are most likely to occur. If service hazards are such that the expense is justified, the casting can be thoroughly covered.

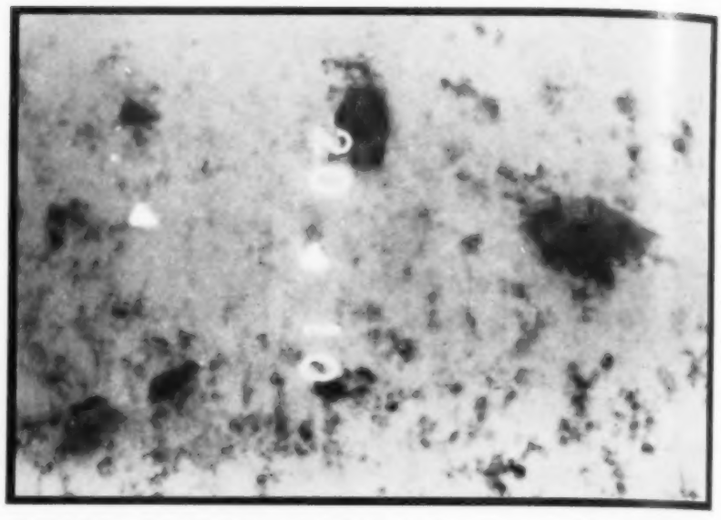
An exact idea of the shape of individual inequalities of section cannot always be had from the film, for the angle of incidence of the X-rays at the particular spot determines whether the flaw will be shown in plan, in cross-section, or in diagonal section. Shrinkage flaws in a certain casting, for instance, as discovered originally on the X-ray film, were roughly round or oblong. When this casting was broken open, the actual defects were more or less crescent shaped, but were placed edgewise to the X-ray target. Such cavities would be shown in their true shape when the rays strike them at the proper angle.

Photographs on page 46 show shrinkage surrounded by solid metal. The location of the radiograph is chalked on the outside of a large cylindrical casting. There was no outside indication of a flaw, but serious porosity was found along a corrugation in the wall. This cylinder was then notched perpendicular to its long axis, and the head broken off. At the bottom of the page is a photograph of a small portion of this casting, showing the defect end-on; the cylinder wall, except at the corrugation, is quite sound, as indeed was proven by the radiograph. The piece was again notched parallel to the long axis of the flaw and broken. The other photograph (at the lower right on page 46) shows the porosity to extend longitudinally along the wall, exactly below where the radiograph was mottled in appearance.

Sometimes castings of this sort are extremely "blowy," containing the ultimate number of flaws possible in a casting without any plain surface indications, except perhaps in one or two places. Such castings can be fairly smooth on the outside, yet the radiograph will be marked up as badly as a victim of the smallpox. Another example of blowy metal is available, where the defects are much less marked than the ones just mentioned, yet careful examination of the radiograph will disclose a shadowy appearance caused by a slight split along the axis of the metal, a defect

which is plainly evident when the casting was broken open.

It is quite easy to differentiate between defects of different character occurring at the same spot. Careful examination of the large spot in the radiograph alongside (more easily seen on the original film than on the reproduction) shows a sharply defined grayish spot, while surrounding the spot, and extending beyond it, there is a black area. The casting was broken through this spot and a slightly enlarged photograph is shown at the foot of the page. A slag inclusion was found to be superimposed upon a shrinkage cavity. The smaller spot seen on the radiograph, and showing the same sort of flaw, was not broken into by the fracture.



Large Spots on Above Film Have Mottled Appearance, Representative of a Slag Inclusion. Below is casting, fractured to cross one of these spots; this stony inclusion is shown about midlength in the view

The large view on page 44 shows, in one X-ray film, practically every common defect occurring in a casting, the result of attempting to patch a broken core. The patches show up as lighter spots on the film, where the metal was slightly thicker as the result of this poor molding practice. One or more of these patches did not hold, with results as shown. An accompanying photograph of the area covered by the X-ray is on page 45, taken after the casting had been marked from the film, and the major defects uncovered with a chipping hammer. If this photograph is slightly turned, in the mind's eye, many of the radiograph markings can be identified on the pot itself.

All of the castings described in this article were scrapped on account of the evidence presented by the X-ray films. Consequently the defects shown may be considered as worse than average. Not a single casting, however, with possibly one exception, would have been rejected by the evidence of careful visual examination — it is not necessary to X-ray castings which have *visible* defects.

The photographs shown herewith, necessarily limited by available space, plus a much larger amount of evidence gathered over a period of two years and not easily presentable in printed form, show conclusively that the X-ray does three things: (*a*) It shows all defects that are known to affect the life of an alloy casting; (*b*) it is easily adaptable to irregular surfaces and sections; and (*c*) it differentiates sharply between defects of different character.

As the highest type of inspection medium yet developed for castings, the X-ray apparatus is quite easily controlled, and delivers uniform and readily understandable results beneficial alike to manufacturer and customer.

EDITORIAL

Heavy Weldings Abroad

A COMPREHENSIVE VIEW OF THE STATUS OF welding in Europe may be had from the important symposium held early in May by the British Iron and Steel Institute, for comparatively few Americans are found among the 150 authors. It is interesting to observe how the influence of economic conditions and psychological factors has affected advances in the various countries. Thus, whereas the art of autogenous welding was born in France, and its Institut de Soudure Autogène is the model organization for study and instruction in the various processes, the practice there still seems to be restricted to relatively minor units. In fact, continental operations seem to be influenced more pronouncedly by German practice and opinions. England, as always, is conservative; lacking a "Welding Society" much fundamental work has had to be done by each manufacturer as he became interested, and there are still many hampering official restrictions. Australians are far bolder and have welded in a big way for a long time, correcting their mistakes as they found them.

In Germany, naval constructors led the way, when after the War they started construction of "pocket battleships." At that time the coated electrode had not been popularized; arc welding with bare or lightly coated ("dipped") electrodes is still favored by Germans for large structures because of their belief that only ordinary skill is necessary to do a consistent job of welding. German engineers recognize that joints of higher impact and fatigue resistance can be made in other ways, but the lower efficiency is provided for in the design. Thus, if S be the permissible stress in the structural steel, fillet welds are designed to carry 0.65 S; butt welds in tension may be designed to carry 0.75 S. Likewise welding is avoided in structures (except ships, strangely enough) which carry sizable dynamic stresses.

Belgian bridge engineers are emerging from the influence of the above restrictions, as is shown by the construction of about 40 bridges, ranging from 150 to 225 ft. span, which carry heavy traffic of all classes over the new Albert Canal. These are of the Vierendeel type, having a parabolic compression member above grade with stiff verticals carrying the floor system and no diagonal members, so lateral forces must be carried by generous knee-brace gussets at the ends — a type unusually adapted to welding. Extensive tests on large scale models of the framing at panel points indicated the proportions for the design, since they located stress maxima at unexpected places. It has been found that the endurance limit of the joints is twice the maximum stress actually imposed on the critical region. Even overpowering loads merely buckle the gusset plates — a type of failure that is easily seen and may be corrected long before actual disaster.

Oft-expressed ideas that structures should be designed for welding and not merely adapted from riveting are achieved in these Vierendeel trusses, and also in the girder types of rigid frames for mill buildings and arenas, now favored in Italy and Central Europe rather than the more conventional roof trusses end-connected to crane columns. This has inspired a great advance in the theory of design of these statically indeterminate structures. Such rigid frames, even though heavier than latticed members, are easier to lay out, assemble by welding and erect, and hence have a lower over-all cost. The various parts of a rigid frame resist combined bending and compression, and welding is an ideal method of constructing members whose depth varies continuously with the varying stresses to be resisted, having proper stiffness in web plates and ample strength at the hips. Furthermore, the transfer of stress is taken along lines which have a far greater aesthetic appeal. In all cases the effort is made to place joints where they can be made (either in shop or field) under the most favorable conditions, and in metal parts of the same or nearly the same thickness.

In passing it might be mentioned that a complete job of welding generally costs more than a complete job of riveting, as far as labor and shop overhead are concerned, and only when a greater saving can be made in weight or col-

lateral advantage should the substitution be made. A practical consequence of the difficulties to be encountered in field welding and erection is that all large European structures are shop fabricated into the largest transportable sections, leaving a minimum of work to be done at the site. Internal stresses in these welded sub-assemblies are not relieved by low temperature heat treatment — the effort rather is to avoid distortion by proper clamping or weighting to the welding table, and carefully scheduling the sequence and location of beads. The idea is apparently that if the assembly has little or no distortion, the internal stresses are of minor intensity. This is probably a close approximation to the actual circumstances until the parts get fairly big and stiff. Just where the danger zone begins is a matter for mature consideration.

Field joints in welded structures are always studied so they may be made with the minimum of overhead welding or work in cramped quarters. (One engineer on a big penstock job testified that not one out of 130 welders examined was thoroughly competent for overhead work with covered electrodes!) Many times, therefore, one finds that welded assemblies are field riveted, or, as in London where noise is restricted, joined with fitted bolts. This economical practice also avoids the very real danger associated with welding a rigid seam — that is, putting heat into parts that are so rigidly held in a massive structure that there is no chance to move when the metal cools and contracts, and hence building up very large internal stresses.

The matter of transportation has had two interesting effects in two different countries. In Australia freight rates are assessed on the basis of value of material shipped, and since shop costs (either in riveting or welding) add so greatly to the value of the members, the practice there is to ship beams, shapes and plates from the mill to the site and do *all* the fabrication in the field!

In the other instance, high strength low alloy steel was used in the main members of a 185-ft. arch bridge in Sweden, so that the subdivisions of the arch, and the floor beams required for economical erection could be transported and erected with available equipment. The steel used contains 0.20% carbon, 1.0% manganese, 0.30% silicon, 0.50% chromium, and 0.75% copper; its ultimate strength is about 75,000 psi., yield point 50,000 psi., and elongation 20% in 10 diameters. This material was welded with rod giving somewhat lower strength in all-weld-metal test pieces, because the engineers could not secure electrodes which equaled the parent metal and yet had good toughness and did not tend to crack during cooling. (Obviously, however, the ultimate strength of weld metal must be well above the yield point of base metal, else the weld will inevitably crack on cooling.) Design stresses in the welded joints in this material were 25% higher than in medium structural steel (60,000 psi. ultimate).

Brakes and Bearings

READERS OF METAL PROGRESS ARE INDEBTED to Dr. Kotaro Honda, the distinguished Japanese metallurgist and honorary member of American Society for Metals, for the article by two of his protégés on pages 52 to 55 about abrasion. It would seem that these investigators have hit upon a new fact that will be the means of explaining many things about wear and bearings — namely that wear between two metals running dry will be greatly modified by a third metal or substance which is not a lubricant but has the ability to imbed itself on the rubbing surfaces of the other two, filling in the microscopic (even sub-microscopic) hollows and roughnesses existing even on a polished surface.

The usual explanation contained in textbooks about the structure of a bearing metal, like babbitt, plastic bronze, or leaded copper, is that it contains a hard micro-constituent to resist wear, and a soft matrix to enable the hard particles to conform gradually to the load. Sometimes it is pointed out that the soft matrix wears away, leaving the hard crystals standing out above valleys which are channels for oil. To this conception now may be added the thought that the soft matrix, in wearing away, fills the irregularities on the journal and on the surfaces

of the hard constituent in the bearing. If these irregularities or protruberances are high enough to pierce the film of lubrication, heating, scoring and seizure result; if the hollows between the irregularities are filled in by a plastic material, there is much better chance for all the metal to float on the oil film. One might also guess that this filling-in action is a prime function of the sulphur and its compounds which have proven so valuable for improving the load-carrying ability of lubrication greases.

In these experiments on the mutual rubbing action of three or more materials, isn't there also a hint of the logic behind present-day automotive practice in brake drums and linings? The lining is a relatively soft carbonaceous or fibrous material whereas the best drum to resist wear is of eutectoid composition — hard cementite plates to withstand the abrasion and soft ferrite filling to smooth out the irregularities on the exposed ridges of carbide.

Trends in Galvanizing

GALVANIZED SHEETS PRESENT A PRACTICALLY perfect example of what is likely to happen to an article of merit as soon as its manufacturers start to shave a little here and make a short cut there — producing to a price rather than to maintain a reputation and improve utility. As pointed out by R. M. Roosevelt, president of American Zinc Institute, in a recent address to that body, the amount of zinc on galvanized sheets was reduced during the War from about 2 oz. per sq.ft. (that is, 1 oz. on each side, or a layer about 0.002 in. thick) to hardly one-third as much. This action was prompted primarily by the exorbitant price charged for the zinc, but also cut associated costs in the finishing mill by speeding up the work in the galvanizing kettle. The growing use of cold rolled strip, none too flat, rather than annealed sheets, also promoted a thinner coat of zinc (and more variable in thickness) after passing through the exit rolls in the galvanizing machine.

The reckoning was not long delayed. Durability of the sheets was cut in almost exact proportion with the zinc. Galvanized, which was once a favorite material for roofing and siding in the middle West, both for industrial and for farm buildings, speedily acquired a bad name and was replaced by lumber and composition materials. In 1921 the zinc used on galvanized sheets amounted to 36% of the total zinc used in this country; in 1932 the figure had fallen to 24%.

Even though the sheet steel industry could shut its eyes to the inroads of competing materials, it was a matter of life or death to producers of "prime western zinc," for that is the grade used generally by galvanizers. Consequently the American Zinc Institute in 1931 sponsored a campaign for better coatings, advertising and promoting a "Seal of Quality" brand which required a return to the pre-War standard of 2 oz. per sq.ft. It has carried forward its campaign single handed, for apparently members of the steel industry have been so much interested in maintaining the suppositious value of their own trade names (already debased by their own production methods) that concerted action by the Flat Rolled Steel Institute was impossible.

As a matter of fact, only a negligible amount of "Seal of Quality" sheets is being sold. Some discussion is indulged in as to the responsibility. The extra allowed by the Steel Code of $10 a ton for a thicker coating on 28-gage is certainly not much more than the cost of the extra zinc at the present price plus the extra care required to produce a really uniform coating of required thickness. Hence the producer gets no immediate return. A greater obstacle is the reluctance of jobber and dealer to invest considerable extra sums in duplicate stocks of ordinary and extra heavy galvanized sheets, since by his code he is allowed to charge no more than $10 a ton extra (his own first cost) for maintaining an inventory of this material, and so gets no interest on his added investment.

Perhaps a more important effect of the Zinc Institute's campaign than direct sales of 2-oz. coated sheet has been to increase the average weight of coating on all the sheets on the market. Its investigators found that the so-called standard galvanized sheet produced in 1930 carried an average of close to 1.0 oz. zinc per sq.ft., with some sheets going as low as 0.6 oz. At the present time, the average is 1.25 oz. zinc per sq.ft.

While this means a good deal to the sellers of zinc, it doesn't mean so much in a campaign to regain lost users of galvanized sheet. Present discussion of relation of life of such material runs into terms of 3 to 7 or perhaps 10 years. Both zinc producers and steel makers may well raise their objectives far beyond this. As a manufacturer recently said at a meeting in England — "I am not so much interested in results of life tests of 3 or 3½ years as I am in returning to that standard of my youth, when galvanized iron and wire was expected to last at least 30!"

REDUCING ABRASION

by compound

contact pieces

by S. Saito
and N. Yamamoto
Sumitoma Steel Works
Osaka, Japan

SOME TIME AGO WE BEGAN TO INVESTIGATE the problem of abrasive wear, hoping that we might find something to enable us to reduce the excessive costs of replacing brake shoes and wheel tires. The results of the study are of interest to a theorist, but even more to a maintenance engineer, since they have reduced brake shoe replacements to a small fraction of former figures. They have also indicated means whereby the mutual wear of trolley wires and collecting shoes may be largely decreased.

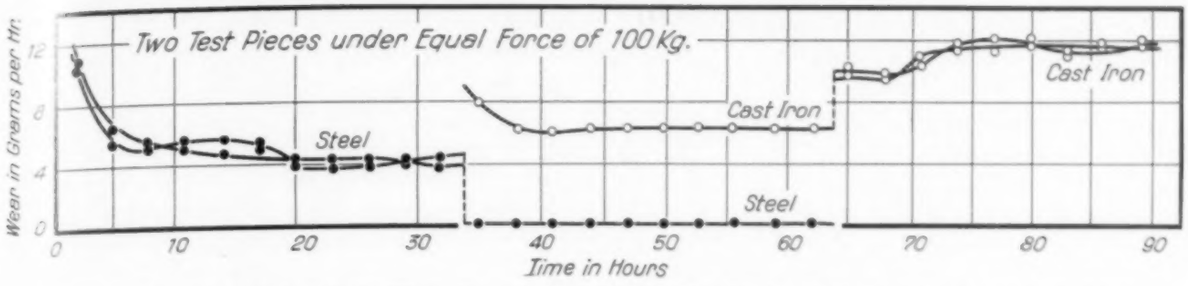
Former studies on abrasion can be classified into three general groups: *(a)* Dry abrasion against a standard, such as a cast iron plate or emery paper; this method neglects the wear on the standard. *(b)* Relative abrasion of two dry elements in contact, as is done with the Amsler machine. *(c)* Either of the above methods when lubricants are used.

Our results were quite different because we placed three or more members in wearing position. Having in view the primary object of our research, we used an instrumental set-up that would imitate the action of brake shoe against wheel. As seen in the first view on the opposite page, we mounted a 36-in. steel tire on the table of a vertical boring machine and rotated it at 37 r.p.m. Test pieces were pressed against the machined tread at diametrically opposite points, taking care that both of them rubbed against the same band of metal on the moving tire. These two test pieces were of various materials, as later to be described, and were held up to their work by a fixture enclosing a coiled spring, whereby the force could be varied from zero to 225 lb.

The amount of wear was measured by weighing the three test members periodically. The wear of the tire could not be computed accurately, as it was very small in proportion to its weight.

The tire was an ordinary rolled engine tire, made of carbon steel approximating S.A.E. 1075 in composition. It was not heat treated, but finish turned in a lathe. In the first experiments, the rubbing pieces were cast rods, turned to 1¼ in. diameter, either of cast steel (0.70% carbon) annealed at 1550°F., or of cast iron of brake shoe analysis (carbon 2.80%, silicon 1.37%, manganese 0.73%, phosphorus 0.79%) not heat treated. The first diagram shows the progress of a typical run.

In the first third (33 hr.) of the test period, a steel rod was in both fixtures, pressed against the tire with equal force: 225 lb. Points plotted represent wear in grams per hour; after a "running-in period" of about 7 hr. the wear became nearly constant at 4.5 grams. At the end of 33 hr. one of the test pieces was replaced by a cast iron piece, and the first weighing showed that wear on the remaining steel piece was practically zero (on the order of 0.01 gram per hr.). However, the cast iron piece quickly settled down to a constant wear of 6 grams per hr. When that had proceeded long enough to indicate that no change was likely to take place, the remaining steel test piece was replaced by a second cast iron piece.



Rate of Wear of 1.25-In. Rods When Pressed Against Steel Tire With 225-Lb. Force. In first part of test two steel rods were used; in middle part one steel and one cast iron rod, and in third part two cast iron rods.

As noted on the curve, abrasions then greatly increased as compared with steel in the first part of the test and even greater than the wear of the cast iron rod when combined with steel as in the second part.

It will also be noted that the wear on the cast iron increased during running-in, but finally became stabilized at about 11.5 grams per hr. Evidently we must consider a mutual effect of material when running in dry rubbing contact. It is as though some materials will act as lubricants to each other, each one then wearing less than though it were working alone.

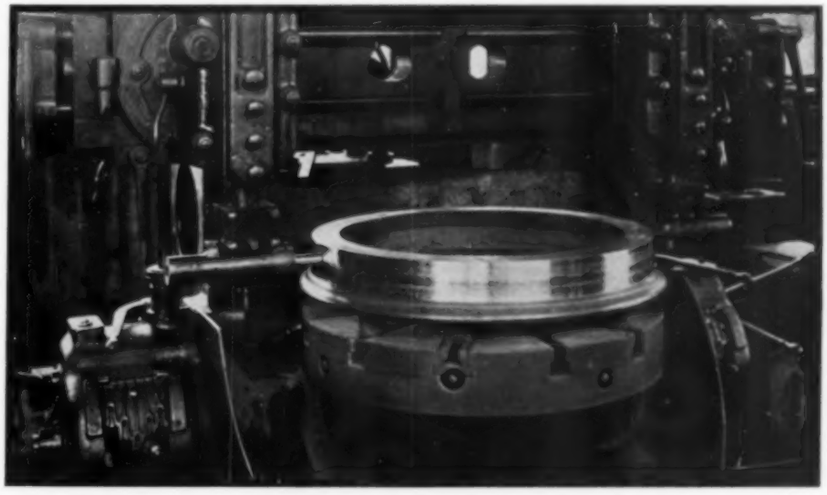
Next we desired to determine what effect pressure had upon these results. From a mass of data the diagram on page 54 is representative. The full lines show the result of steel and cast iron on the steel tire when the steel rod is held at a constant force of 225 lb. but the cast iron at the various smaller pressures plotted on the horizontal ordinate. Each plotted point was measured after the lapse of the running-in time, which we have fixed at 5 hr. after each change of pressure. It will be noted that abrasion loss of the steel is reduced greatly when the pressure (and wear) of the cast iron is quite low. It is also evident that the pressure on the cast iron must be held well below 175 lb. (about 150 lb. per sq.in. of contacting surface for this specimen) in order to avoid excessive wear on it, and fortunately at these lower pressures the associated wear on steel is very small.

When both rods are of cast iron this critical pressure is even lower — about 100 lb. per sq.in. of contacting surface.

Other materials than cast iron have a great influence on the wear of steel against steel. If, for instance, the cast iron rod of the above described test at variable pressure is changed to teak wood and tests made in the same order, the results are shown in the dotted lines in the same diagram. It resulted in a practical cessation of abrasive wear of steel against steel (actually on the order of 0.01 gram per hr.).

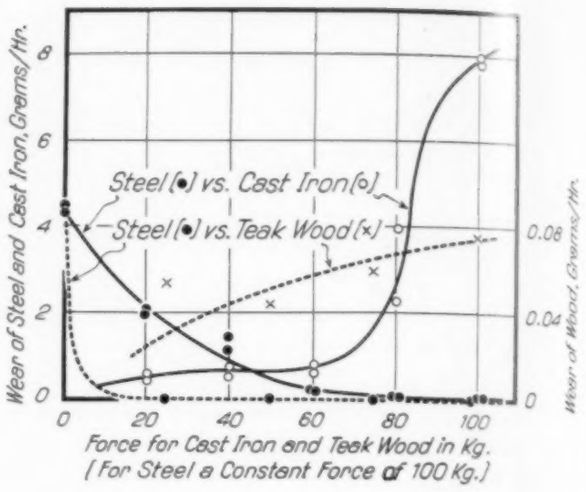
Other similar tests were made with artificial resin, carbon rod, hard rubber and asbestos cloth used in place of the cast iron rod, and all these tests revealed similar effects in reducing the abrasion of steel against steel. Copper, brass and aluminum had not as great an influence as the above materials in reducing wear.

When these findings were applied to the design and operation of brake shoes on railroad rolling stock the results were extremely satisfactory. In place of the customary cast iron, we



In a Study of Brake Shoe Wear, Tool Posts on Either Side Carried Spring Fixtures Which Pressed Test Samples Against Wheel Tread at Opposite Points

Rate of Wear of Steel Strongly Pressed Against Steel Is Greatly Reduced by an Auxiliary Wearing Piece of Cast Iron or Teak Wood Held Down Lightly



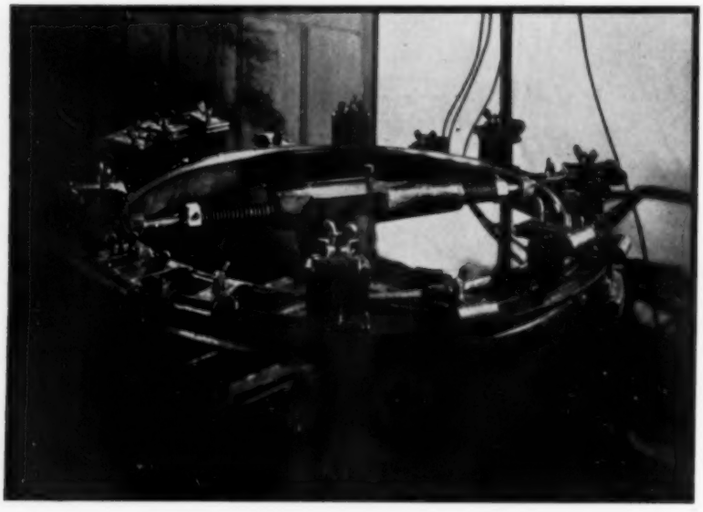
introduced a pair of steel and cast iron shoes, or steel and wooden shoes, with draft rigging properly adjusted to prevent pressures above the critical during normal operation. On a suburban electric railway it has been ascertained that the steel brake shoes wear about 4% and the cast iron shoes 85% as rapidly as when only cast iron was used. When pairs of steel brake shoes were used, their combined wear was about 70% of the wear when only single cast iron shoes were used.

Both extensive laboratory work and road tests have proved that the coefficient of friction between steel shoe and the steel tire is higher than that of cast iron shoe against steel tire. We have also observed that when two shoes are used, steel in combination with cast iron, their respective coefficients of friction remain almost unaltered. The brake effect (deceleration of a moving car) therefore is not reduced. Our observations have proved that abrasion and coefficient of friction have no relation to each other, although generally it is accepted that the coefficient of friction is less with articles having the least amount of wear.

We are certain that these observations can be applied to advantage for other purposes, as, for instance, piston rings and bearings.

From the success of these experiments we were encouraged to study the wear of collecting shoes against trolley wires. Equipment was somewhat different, in that a hoop of copper wire was held at numerous points in a circular jig. It is shown in the adjoining photograph.

Wear of Trolley Wire Was Studied in Fixture Where Two Rubbing Pieces Are Carried at the Ends of an Inner Rotating Arm



A horizontal bar, pivoted at the center, was spun at the rate of 122 r.p.m.; at either end was an adjustable spring fixture carrying contact pieces. In most of our tests the contact pieces had an area of 0.12 sq.in. and the spring pressure 13 lb. Abrasion of the materials under test was weighed at intervals of 2 min.

Wear of Trolley Wire

Copper contact pieces were used in the first experiment; the testing conditions then resembled the actual system for collecting electric current as used in electric railway service. Total abrasion of the trolley wire is shown on the last diagram, which also contains a line sloping sharply upward, referring to the wear of one of the two copper contact pieces.

Lines at the bottom of the diagram show how the abrasion of both copper trolley wire and contact piece is reduced almost to zero by replacing one contact piece in the moving arm with a piece of hard rubber. In fact the wear on the copper was so slight that it could not be accurately weighed.

Other experiments, conducted when using aluminum, lead, wood, bamboo, leather, vulcanized fiber, or artificial resin also resulted in a great reduction of the wear of the copper members. The least wear of all three members was obtained when artificial resin was used; the total abrasion was only a fraction of one per cent of that noted when all contacts were of copper.

Corresponding results were also obtained even when the copper wire was replaced by a steel wire.

We also conducted the above experiments while passing 50 amperes of alternating current through the copper contact piece to the wire, in order to obtain identical conditions to railway service. When the electric current is passed the wear is somewhat increased in all cases, but the phenomena of relative wear, when three members are used in combination, existed unaltered. We have also conducted extensive tests of long duration with the same results.

Mechanism of the Action

The true theory of the above phenomena concerning mutual wear of three bodies is not clear, but we advance the following:

Microscopic as well as macroscopic observations showed that abrasion between steel tire and steel contact pieces caused a roughened wear-surface on the tire as well as on the contact pieces. When one of the steel contact pieces was changed to cast iron, however, the wear-surfaces of all three became very smooth.

It is supposed that when pieces of a ductile material such as steel are put into sliding contact with each other, innumerable microscopic protuberances appear, like the teeth of a tiny gear. These protuberances are easily broken off by clashing with similar ones on the sliding part and this, in turn, creates new protuberances, and therefore excessive wear.

On the other hand, when a cast iron contact piece is introduced, its wear produces very fine particles, owing to its brittleness. These fine particles embed themselves in the gaps between the protuberances of the steel surfaces so that the contact surfaces become smooth, and little wear results. If these fine particles that fill up the gaps have the property of preventing oxidation of the steel, the rate of abrasion will be even further reduced.

The same theory holds true in the case of the three members, copper against copper and a brittle element like hard rubber or artificial resin. We have also observed that wear was reduced when copper and copper was used in combination with a soft ductile metal like tin or lead. In these cases, the tin or lead does not grind into fine particles, but owing to its extreme plasticity, the worn parts smear into the gaps between the protuberances of the contact surfaces and smooth them. When such a soft ductile material is used as a third member in the combination, the wear of this third member is comparatively high; also the coefficient of friction between the other two is reduced.

From the above observations we conclude that the third member which is introduced to reduce the wear of two ductile materials must have the following properties: *(a)* It must be brittle, and in wearing it must be reduced to very fine particles. *(b)* The hardness of the reduced particles themselves must be lower than the other members. *(c)* If the particles have also the property of preventing oxidation of the other members, they are more effective in reducing wear.

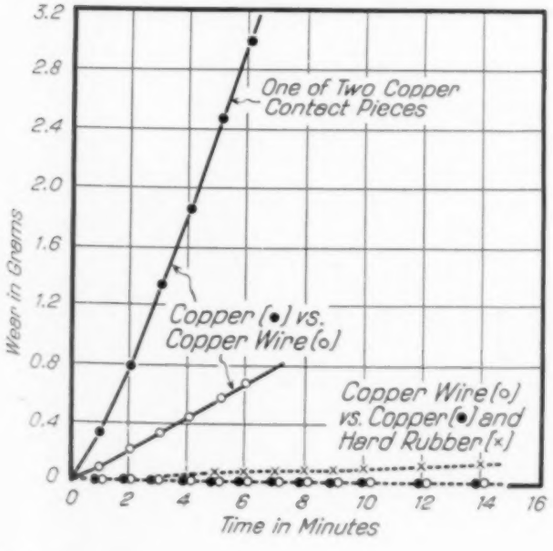
If the third member is a ductile material it must be considerably softer than the other two members.

According to the above theory, it is essential that the main medium, which in one case is the steel tire and in the other is the copper wire, must always be a ductile material. If it were changed to a non-ductile material (say cast iron) then the phenomena under discussion will be changed.

In case the two contact pieces of different material are combined into one piece, the wear in thickness of both materials of this combined contact piece must be the same, and the protective action shown in the middle part of the first test cannot be secured.

Owing to the running-in time being somewhat akin to a hysteresis effect, it is not necessary that the third member be constantly in contact — it can be pressed to the main medium intermittently, and still be effective.

Copper Rubbing Against Copper Wears Rapidly, But Almost None When an Auxiliary Rubbing Member of Hard Rubber Cement or Artificial Resin Precedes the Copper Contact



METAL FOR HOUSING

stainless steels & enameled iron

by M. J. R. Morris
Chief Metallurgical Engineer
Central Alloy Division
and Karl Kaulz
Ceramic Engineer
Republic Steel Corp.

THE EXTENSIVE USE OF STEEL PRODUCTS ON building exteriors is one of the most significant of present-day trends. The idea is not new; it has been tried many times in past centuries with but little success, since attempts to use metal exteriors on buildings have been handicapped by short life and enormous upkeep. Today, the everlasting beauty of stainless steel and vitreous enameled iron has been placed in the hands of the architect and owner and offers them many advantages not thought possible before.

In the building industry today there is, generally speaking, a prejudice against the use of metal for exteriors. Any new material must undergo this handicap until it has proved its worthiness. Later will be pointed out various influences tending largely to overcome these prejudices and allowing steel products to take their proper place in the building industry.

Wrought iron was probably the first metal used in an architectural way. On the old baronial stone castles of medieval times, wrought iron was used for decorative and ornamental fixtures and for grilles and window bars. Many fine examples may be found in American museums.

The earliest large-scale application of metal on buildings was sheet lead, used for roofing cathedrals and state buildings in Europe. This metal was properly chosen from the materials then available; it was durable, easily erected and reduced the roof load considerably from slate or tile. In addition it withstands severe storms and presents a pleasing appearance. Copper followed lead as a roofing material, still further reducing roof load, maintaining the ease of application, and adding an interesting play of color. The amount of roofing so used was limited, however, and only the nature of the buildings permitted the necessary cost.

In comparatively recent times, coated iron and steel products such as tin plate, terne plate, and galvanized iron have been used for siding and roofing in factory and small buildings where economy of materials and ease of erection were paramount. While some such buildings have had long life where atmospheric conditions are favorable, these modern coated metals are not regarded as having any degree of permanence.

It is significant that an industry frequently gets a great impetus from an unrelated source. The building of ships has progressed rapidly in the last hundred years, when wooden ships began to be replaced by wrought iron and later by steel. With the use of steel came increased size, speed, safety and comfort impossible in the wooden ship. Here the prejudice against metal was quickly dispelled and now the very fact that ships are steel gives a feeling of strength and security, of warmth and comfort.

While it is a common belief that metal structures are cold and are difficult to heat, steel ships are subjected to the most severe weather condi-

An Address on This Subject Was Recently Presented to American Chemical Society

tions and always ride in cold water, yet the passengers are quite comfortable. Another example to the contrary is the steel railway coach. Here passengers ride luxuriously although entirely surrounded with steel. In fact, the common complaint is against heat rather than cold. In the new type of coach even greater comfort in all seasons is afforded by the use of sealed windows and air conditioning.

Similar analogies are seen in the aircraft industry. The modern transport airplane has a metal skeleton of tubular construction overlaid with flat metal products, probably the most advanced use of low-weight, high-strength metal ever developed in a product. With little or no insulation, passengers seldom complain of cold, yet very low temperatures are encountered. In the recent stratosphere flight by the Army Air Corps, the lowest temperature recorded inside the gondola was 32° F. above zero, although temperatures as low as minus 94° F. were recorded outside. This gondola was constructed of a very light metal shell (magnesium alloy) and had no insulation whatever, only black paint on the outside and white paint on the inside. These facts are significant. Ships, railways, and aircraft have overcome problems and prejudices that have delayed building construction on land, but which will exert an increasing influence on steel products as coverings for buildings.

Steel products used for building exteriors have many architectural advantages:

1. Time required to build with pre-fabricated metal is much less than with stone or brick. Large surfaces are covered as a unit, with a minimum of weight handled.

2. Ease of erection is an item of great consideration. The stainless group of steels lend themselves readily to welding and riveting directly to the steel skeleton. They may also be attached with clips and screws. For vitreous enameled iron, various methods of fastening have been devised such as interlocking keys, clips, and bolts.

3. Exteriors of steel make much thinner walls, which in turn create more effective space. In large buildings this alone is worthy of careful consideration by the owner.

4. Walls of metal construction lend themselves admirably to insulation against heat and sound. Tremendous strides have been made in this direction; many forms of insulation, such as cork-board, fiber-board, rock wool, and asbestos are now available for specific cases. For instance, a $\frac{1}{8}$-in. sheet metal exterior to which a 1-in. fiber-board is cemented and finished inside with $\frac{1}{2}$-in. coat of plaster would weigh 8.5 lb. per sq.ft., transmit 0.254 B.t.u. per sq.ft. per hr. per °F. temperature difference, and have a total thickness of $1\frac{5}{8}$ in. A solid masonry wall of equivalent heat flow would have a weight of 85 lb. per sq.ft. and a total thickness of $10\frac{1}{2}$ in., including the furring strip and plaster. These figures clearly show the advantages.

5. The strength and safety of all-steel buildings has been amply demonstrated in regions of severe windstorms and tornadoes. Steel structures remain when wood and masonry are demolished. A steel building is naturally fireproof, especially if insulated with a

Detail of Entrance and Facade of a True All-Metal House. Frame and floors of pressed sheet, siding of enameled iron. Courtesy Ferro Enamel Corp.

Another Idea, Vigorously Promoted, Is That American Conditions May Best Be Met by Steel Frame, Shop Fabricated in Standardized Sections. Frame of this 7-room, $7000 house was completely erected in 75 man-hours. Contains centralized plumbing, heating, and air conditioning units, shop fabricated. Courtesy Berger Mfg. Co.

mineral or inorganic insulation. That the safest place to be in electrical storms is in a steel building, properly grounded, has long been known.

6. Another factor promoting the advent of the all-steel building is air conditioning. This industry is increasing rapidly in versatility, and it is predicted that before another decade has passed, houses and buildings will be so constructed and sealed that windows will probably never be opened.

7. Declining lumber supplies have forced builders to look for other more durable materials with which houses of the future may be fabricated. With extensive use of stainless steels and vitreous enameled irons, the cost of buildings will be reduced in spite of increased lumber prices.

Several advantages of stainless steel as an exterior covering may be cited, principal among which, of course, is that it is rustproof, non-corroding, and permanent. It will not tarnish or become dull when exposed to atmospheric agencies and its gleaming beauty is unequaled. It is available in many finishes, varying from mirror-reflecting to a frosty silvery tone. It cannot chip, crack, or wear thin; it is not plated but the same metal all the way through. It can be cleaned easily of any lodgment of dirt or grime with soap and water or various commercial cleaning solutions. One of its outstanding characteristics is the ease with which it can be fabricated by drawing, punching, shearing, riveting, welding, soldering, brazing, and silver soldering. These facts have been proven by the extensive use of the 18% chromium, 8% nickel alloy for exteriors on several skyscrapers — constructions which have received much publicity.

Vitreous enameled iron also possesses many architectural advantages: It has permanent beauty with an unlimited range of color in either bright or matte finish. Any design or painting can be faithfully reproduced in original colors. The iron, being permanently and completely covered by impervious glass, cannot rust or corrode and is practically everlasting unless grossly abused. Vitreous enamel is very economical in upkeep, the colors never fade, and there is never any need for paint. Dust and grease do not adhere firmly to the hard, smooth surface; simple washing with soap and water will restore the original beauty. While the enameled pieces must be used as made, any desired shape can be formed in the bare iron and this later covered with enamel, baked on. Finally the material is readily available, as competent enameling concerns may be found in all larger cities.

At the Century of Progress Exposition in Chicago there were erected several houses whose exteriors were of vitreous *(Continued on p. 78)*

LETTERS AND COMMENT

on items of interest today

Balanced Blast Cupola

BIRMINGHAM, ENGLAND — With reference to Dr. Giolitti's correspondence on Cupola Practice which appeared in your March issue, we presume that he is not familiar with the developments that have taken place in England during the past few years. The British Cast Iron Research Association, since its inception in 1921, has always been particularly interested in the cupola furnace, and after a considerable amount of work, a new type of cupola was developed, which has become known as the "balanced blast cupola" (U.S.A. Patent No. 1,853,120, British Patent 333,322). In the last four years over 80 furnaces working on this system, with a total output of nearly 500 tons per hr. have been put into operation. Although the majority of these furnaces are in British works, installations have been made in Australia, the United States, India and on the continent of Europe.

The new system can be applied both to new and existing furnaces of all sizes from two tons per hour upwards. The principle of operation is that of controlling the air supply at the main tuyeres by finely adjustable screw valves fixed to the wind belt. Above these valved tuyeres are three rows of smaller auxiliary tuyeres all delivering air from the same wind belt. By regulation of the main air supply and auxiliary air through the small tuyeres (which are also adjustable) almost complete combustion of the coke is obtained, as can easily be proved by analysis of the top gases. In a well designed and correctly adjusted balanced blast cupola these seldom contain more than 1.5% carbon monoxide by volume, as compared with 10% to 12% carbon monoxide normally found in the top gases of a well designed ordinary cupola.

The thermal efficiency of the new cupola is reflected in the temperature of the molten metal and also in the coke consumption, which is usually 20% to 30% less than on a well run normal cupola. The use of a smaller amount of fuel results in a lower carbon and sulphur pick-up and enables the foundry to produce high quality iron at a degree of superheat more comparable with that obtained in the newer types of melting furnaces. Experience has shown that the metal from the balanced blast cupola is superior to that obtained from the ordinary cupola. Because of the relatively non-oxidizing atmosphere obtained, the metal is practically unoxidized and gas-free, lies quietly in the ladle and mold and helps considerably in the avoidance of blowholes and shrinkage cavities. In one foundry where the cupola was installed, the scrap due to defective castings over 12 months was reduced by 85% of its original figure, averaged over several years, and reductions of 30% of the scrap figures are common. The cupola is particularly suited to the melting of charges containing steel.

By means of overhead slide shutters the main tuyeres can be closed temporarily to air supply and can thus be kept free from frozen slag. As a consequence internal obstruction and "bridging" are unknown and in one large works the cupola has been worked regularly for 20-hr. periods without trouble. The furnace requires far less attention during melting, and poking of

the tuyeres has also been completely eliminated.

Due to the greater ease of air control on the new cupola, the melting rate can be varied through fairly wide limits, and outputs from 20% above to 40% below normal have been maintained for long periods.

We consider the above notes are sufficient to show that great advances are being made in cupola practice in Europe at the present time and in conclusion we quote, with permission, from a letter received from a very able and well-known British foundryman. He stated that the balanced blast cupola is "a masterpiece of practical iron founding which I believe to be the best now obtainable for ordinary foundry grey iron. I make this statement after a very detailed visit to works where these cupolas are in operation."

J. G. PEARCE

Protection of Radium Workers

LONG ISLAND CITY, N. Y. — A good deal has been published in recent years on the application of radium or other radioactive materials to the problems of non-destructive testing of engineering materials. The value of this work has been well recognized; gamma-ray inspection is particularly useful whenever X-ray examination ceases to be practicable. Because it seems to be very simple, a great deal of work has been done by inexperienced people. Yet the safe handling of radium requires much care and many precautions. Even today a lot remains to be learned about the ultimate reaction of the human organism to frequent exposure to radium and other radioactive materials, like radon, mesothorium, and the like.

In a recent paper on this subject in the *British Journal of Radiology*, Messrs. Kaye, Bell and Binks describe the results of researches at the National Physical Laboratory. While their work has been done with medical application in mind, most of the recommendations should be observed in our industrial work, for we are dealing with much larger quantities of radium and often have to work under much worse conditions than the routine medical attendant.

It has been confirmed by the British investigations that a certain amount of rays will penetrate the containers in which the radium is ordinarily carried. The necessary thickness of lead to protect the worker who has to carry the radium is given in the first line of the attached table. While the results of gamma-ray exposure are cumulative, they will wear off after a certain time if one does not handle radioactive material in the meantime. It is quite obvious that the worker cannot keep at a safe distance when planting the radium seed and when taking it off again. He, therefore, should have everything prepared very thoroughly so that he can fulfill his duty as quickly as possible.

In industrial gamma radiography we deal with exposures which last for hours. Whenever possible, this work is done at night, but it frequently happens that it must be carried on in working hours. In such cases the area within the tolerance limits should be screened off so that nobody can enter the exposure zone, or a lead protection employed to screen off a smaller area. Thicknesses of lead for occasional exposure, given in the table, apply to cases where personnel may reasonably be expected to pass the exposure zone from time to time.

It appears that very heavy containers are required to transport radium from place to place. We recommend that this container hang between two long wooden bars which can be carried from each end, and the men can stay a fairly large distance away from the source of radiation.

HERBERT R. ISENBURGER

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WASHINGTON, D. C. — After studying the original article by Messrs. Kaye, Bell and Binks and H. R. Isenburger's above condensation of the same, we find that there are several additional points that should be mentioned and taken into consideration when these data are applied to radium used for radiographic rather than medical purposes.

The data as presented by Kaye, Bell and Binks are calculated to apply to persons handling radium in medical centers for 7 to 8 hr. daily.

Protection from Radium Radiation

Proximity	Amount of Radium		
	0.05 grams	0.5 grams	5 grams
Thickness of Lead for Protection			
Close up	3 3/4 in.	5 in.	6 3/4 in.
3 ft. occasional exposure	1/4 in.	1 3/4 in.	3 3/4 in.
3 ft. continuous exposure	3/4 in.	2 3/4 in.	4 1/2 in.
15 ft. occasional exposure			1 in.
15 ft. continuous exposure		1/8 in.	2 in.
30 ft. occasional exposure			1/8 in.
30 ft. continuous exposure			3/4 in.
Safe Distance from Unprotected Radium			
Occasional exposure	3 ft.	10 ft.	33 ft.
Continuous exposure	6 ft.	20 ft.	61 ft.

The table included by them is therefore based on a so-called tolerance dose of "0.2 röntgens in a normal working day of 7 or 8 hr., or 10^{-5} röntgens per second over a period of time." Thus the lead thicknesses given in the table afford adequate protection to workers who may be at the specified distance from the radium throughout the day.

There are few instances in which such constant proximity is required in radiography. In most cases in which radium is used for industrial radiography, a portion of the room can be screened off to protect passers-by and there is no need for the operator to remain near the radium, or even in the same building when the exposure is made. The films and the appliance for holding the radium capsule can be placed in position prior to removing the radium from the portable container. The operation of transferring the radium from the container to its position for use should require only a few seconds, certainly less than half a minute, and during this time there is no need for the operator to be less than one foot from the radium capsule. The same circumstances apply when the radium is being removed and replaced in the container.

As Mr. Isenburger has pointed out, the exposures in radium radiography are long and the number of changes to be made during one day are therefore small in number. Thus the actual exposure suffered by the operator is limited to a few minutes per day unless he is unduly careless.

The table presented by Mr. Isenburger is also misleading in that he states "in our field we are dealing with much larger quantities of radium . . . . . than the routine medical attendant" and fails to state that there is no record of as large quantities as 5 grams of radium ever having been used in industrial radiography — even 2 grams. In fact, it is only in rare instances that as large a source as 500 milligrams (0.50 grams) is used and the amounts of radium usually vary from 100 to 300 milligrams (0.1 to 0.3 grams).

By examining the table it can be seen that even with half a gram of radium the distance required to protect a person from continuous exposure is only 20 ft. With 0.2 grams the distance is only 10 ft. for continuous exposure. These distances are even less for occasional exposures. The space required to handle the usual radiographic examinations safely is, therefore, small.

The British workers also made a rather complete study of portable containers for transporting radium. They found that the small wooden containers lined with 1 cm. (0.39 in.) of lead used for transporting radium by hand are suitable for occasional handling of small quantities (100 milligrams or less) of radium. If larger quantities of radium are to be transported larger boxes fitted with centrally located lead-lined containers should be used. These workers also noted that distance gave more protection than lead and that a light bulky package employing no lead might be more effective than a smaller lead-lined container. They also designed several portable containers weighing less than 11 lb., the largest being a cube with 12-in. sides which gave adequate protection in transportation. Since transportation of radium does not necessitate continuous handling, it is difficult to see the need for radium cases so large that two men would be required to handle them.

C. W. Briggs
R. A. Gezelius

Quality of Electric Steel

arc vs. induction

SCHWEINFURT, Germany — Production of steel in coreless induction furnaces has continually increased in the last few years, particularly of high quality steels and high speed tool steels, and it is frequently alleged that the high frequency steels are better than those made by other melting methods.

It is, of course, particularly important for the consumer to be able to evaluate the quality — a matter of considerable difficulty. In our own operations (SKF in Germany) our experience is to the effect that there is, in general, no difference between steels from the coreless induction and from the electric arc furnace insofar as chemical composition, uniformity of structure, and carbide distribution are concerned. Our experience is mainly concerned with high speed and die steels.

In this connection two recent articles are of great interest. They appeared in *Stahl und Eisen*, 1935, p. 228 and p. 276. One is by E. Houdremont, H. Kallen, and K. Gebhard of the Krupp organization and the other is by R. Scherer of the Deutsche Edelstahlwerke.

Acid as well as basic melts of high tungsten steels were made in high frequency furnaces of different sizes — 100 lb. and 1 ton capacity at the Krupp Works and 1 and 4-ton furnaces at the Deutsche Edelstahlwerke — and these were compared with similar melts made in arc furnaces.

At the Krupp plant, when melting 18% tungsten, 4% chromium, and 1% vanadium high speed

steel (as well as the 14-4-2 variety) it was discovered that melts from the coreless induction furnace had finer and more uniform carbide distribution than melts from arc furnaces. These extensive micrographic investigations were made on fields magnified 50 and 100 diameters.

Since the retention of hardness at red heat is important for good service of high speed steel, experiments to determine this property were made and showed practically no difference.

A deciding factor in the quality of high speed steel is its service as a cutting tool. To determine this the various steels were hardened at 2300 to 2350° F. and drawn for 1 hr. at 1050° F. Other steels were quenched in oil from 2375° F. and drawn half an hour at 1050° F. Cutting tests were then made on a log of chromium-nickel steel, heat treated to a tensile strength of 145,000 psi. ± 3000 psi. Feed was 0.055 in. and depth of cut 0.200 in. Cutting speeds were 36, 45, and 52.5 ft. per min. These tests indicated no certain difference between high frequency and electric arc melted steels. Likewise no difference could be found between the basic and acid melted high frequency steel.

Studies at the Krupp Works showed that only in the carbide distribution did the comparisons show more favorable results. This was attributed by Houdremont, Kallen, and Gebhard to the circular motion of the high frequency bath, which presumably caused increased nuclear formation — that is to say, a greater number of nuclei resulted in a fine-grained crystallization and therefore in a fine distribution of carbide.

Slag content was somewhat higher in induction steel than in arc melted steel of corresponding quality. This agrees with our own experience.

Tests at the Deutsche Edelstahlwerke by R. Scherer covered three tool steels of the following composition: (*a*) 14% W, 4% Cr, 1.5% V; (*b*) 23% W, 4% Cr, 1.5% V; (*c*) 13% W, 4% Cr, 2.5% V. The following factors were studied: (1) Carbide distribution. (2) Hardness. (3) Soundness. (4) Cutting power.

As mentioned above, these melts were made in 1 and 4-ton high frequency furnaces with acid linings. They were compared with steels of the same analysis carefully made in the basic electric arc furnace.

1. The carbide distribution was determined by a microscopic comparison, and graded by comparison with four standard samples, sample 1 having the best distribution and sample 4 the worst. In the summation there was practically no difference in the two varieties of steels.

2. Hardness of all the high frequency melts was better than the arc furnace steel after air hardening from 2350° F.

3. A number of tapered bars were twisted in order to determine the possible presence of fine cracks in different cross-sections of the steel. An evaluation of the number, length, and width of the cracks was made by comparison with four standard pieces and no essential difference was found. This test was made on the steel with 2.5% vanadium.

4. Lathe tools were heated in a gas muffle furnace to about 2375° F., quenched in oil, tempered for 20 min. at 1025° F. in a lead bath with subsequent air cooling. Hardness of the steel was measured by the Rockwell test. Cutting tests were made with a speed of 60 ft. per min., depth of cut 0.118 in., and feed of 0.040 in. The test log was an open-hearth steel shaft having about 120,000 psi. tensile strength. Shafts were machined from 14 to about 8 in. diameter. No difference could be found between the tools made of high frequency steel and those made of electric arc furnace steel.

It may fairly be said, therefore, that neither the type of melting or the lining makes any difference, if first-class melting practice be followed. The slight differences likely to be due to these causes may perhaps be submerged by the action of the alloying elements.

HANS DIERGARTEN

Solidification of Metals Containing Gases

LONDON, ENGLAND — The papers in recent years by Messrs. I. G. Slater and D. Hanson before the Institute of Metals have drawn attention to the fundamentals underlying the problem of solidification. This work, which has been sponsored by the British Non-Ferrous Metals Research Association, is wisely considering the problem variable by variable. Progress by this method, although it is slow, can be considered to be sure and the information derived of permanent value.

A year ago a paper was presented dealing with the influence of gases on an 8% copper-aluminum alloy, especially in regard to normal and inverse segregation. During the course of a considerable discussion which this paper created, several diverse opinions were expressed on the relationship between the gases evolved and

(Continued on page 64)

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OLD-FASHIONED

SIMPLICITY

TELEPHONE SERVICE in this country is modern. It leads the world. Yet there is an old-fashioned simplicity about the Bell System. This applies to capital structure and financial methods as well as to the nation-wide plan of decentralized operation under centralized control.

The American Telephone and Telegraph Company has only one class of stock and that stock is not watered.

It has 675,000 stockholders living in every corner of the land. Their average holding is twenty-eight shares. No individual or organization owns as much as one per cent of the stock. There are no secret reserves or hidden assets.

This structure is not of recent origin, but dates back many years to the early days of the telephone. It has lived on because it is right and in the best interest of the public. It has been fundamental in making the Bell System a distinctive American business.

Research for the Bell System is carried on by Bell Laboratories. Manufacturing, purchasing, distributing by Western Electric. Both help in giving the country good, economical telephone service.

BELL TELEPHONE SYSTEM

CORRESPONDENCE

the degree of segregation produced. It is interesting that minimum segregation (i.e., neither inverse nor normal) occurs when the value of the cavities is about 2% of the solid metal. If, however, 4% of voids are present inverse segregation to the extent of 0.5% of the copper content is set up, but if only 1% of voids occur, then an equal degree of normal segregation is found.

The discussion centered around the doubt whether the gas evolution influenced segregation. There is also no unremote possibility that both the gas evolved and the segregation may be subordinate effects to some other factor, such as the development of centers of crystallization.

At the meeting of the Institute held this Spring these two authors have shown in a further paper how greatly the density of aluminum may be improved by casting under pressure. It is suggested that the act compresses the gas bubbles into a smaller space, but that very small bubbles still exist within the solid metal. There remains the grave doubt in the minds of many that the gas may not have been evolved into small cavities but may have been retained in the metal itself in the absence of nuclei conditions favorable to the generation of gas bubbles. This possibility forms an interesting suggestion but assumes that the gas, principally hydrogen, is capable of being retained in a supersaturated solution in the solid state. It should be noted that published experiments indicate that hydrogen is not soluble in solid aluminum. The ease with which hydrogen passes from the molecular to the atomic form suggests that it may be possible for the aluminum lattice to store atoms of hydrogen in a condition which can hardly be described as "solubility," such as exists in a gas in the molecular form. The recent work of Smithells and his co-workers shows that hydrogen can pass through solid aluminum, and this is claimed to be evidence of the existence of solid solubility.

From discussion at the meeting, it seems evident that under no circumstances should pressure-cast aluminum be subjected to hot working or annealing, because it is probable that the gas cavities would expand and form blisters which would damage the properties and spoil the appearance of the finished metal.

Although the work is theoretically interesting, there is little possibility of its application to industry unless it is for the manufacture of castings quite unlikely to be subjected to heat. In order to prepare aluminum in a suitable state for subsequent working it is important to reduce or to keep the gas content below a critical value by methods that are coming to be regarded as standard in aluminum works and foundries.

C. H. M. JENKINS

Electric Furnace Iron

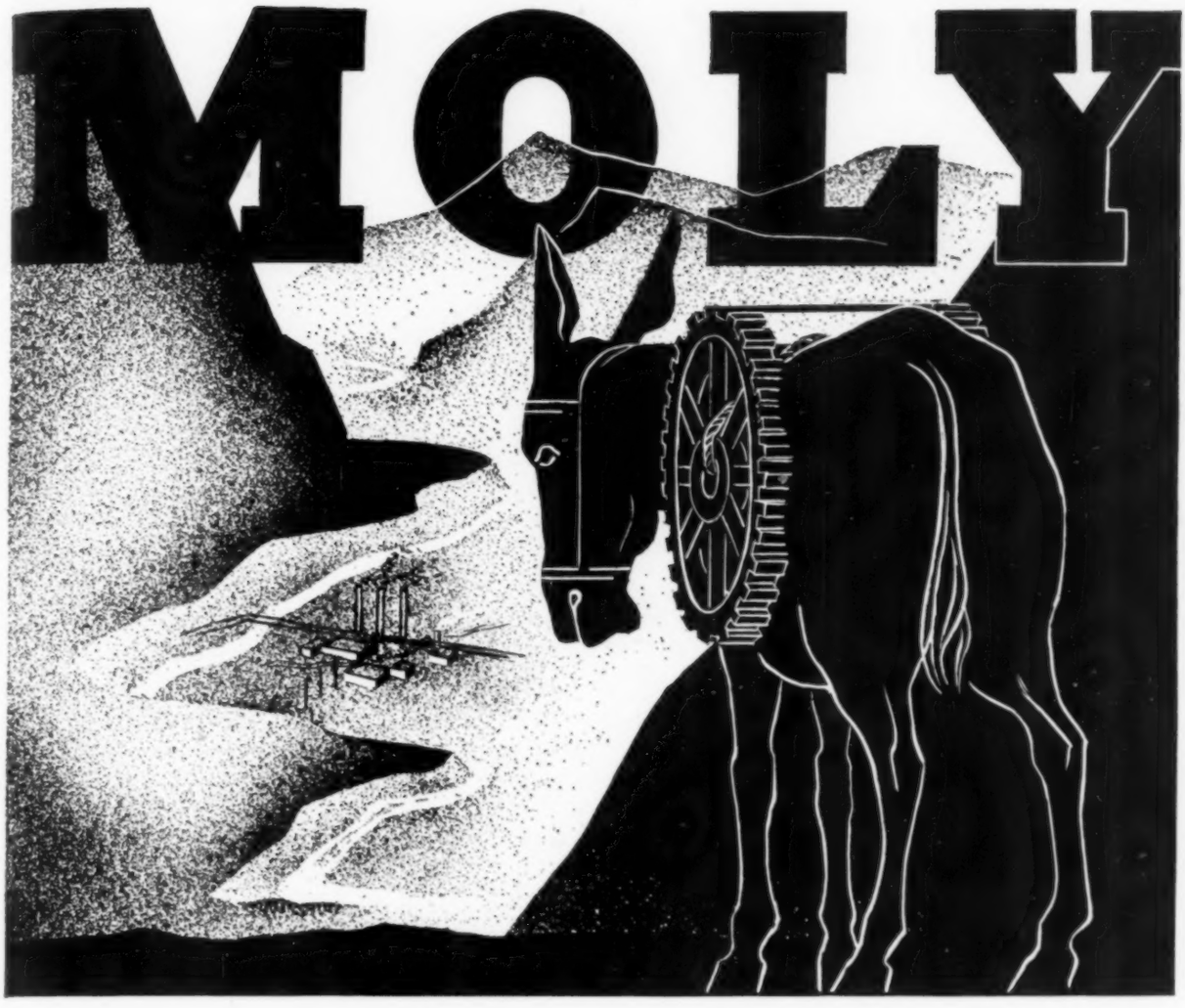
for casting or for remelting

PARIS, FRANCE — The way to obtain high strength iron castings, which has been a pressing problem for many years, is now merely a matter of regulating the foundry practice. The simplest way is to add alloying elements (such as nickel, chromium, vanadium, and titanium) but this is not, in many circumstances, the least expensive one. The desired result may also be attained by four conditions that I indicated long ago: To realize the best strength in cast iron, one should produce a pearlitic matrix holding fine graphite particles in a low carbon iron of sufficient purity.

Such conditions may be easily obtained by the use of the electric furnace: (*a*) The iron can be thoroughly purified by the use of appropriate slags. Either acid or basic linings may be used; the latter will reduce the sulphur to a very low figure, but the former produces more uniform iron. (*b*) The melter can decrease at will the carbon percentage by dilution with steel, and at the same time can regulate the temperature so as to maintain good castability. (*c*) The graphite grain can be refined by superheating the bath and proper choice of the nature and the time of additions (for instance, the addition of silico-calcium, or of high-content ferrosilicon before casting, as I pointed out at the Liège International Foundry Congress, in 1930).

In this way one may obtain tensile strengths exceeding 55,000 psi., shearing resistances exceeding 70,000 psi., and bending loads exceeding 1500 kg. (3300 lb.) on the small French test piece.

The great drawback of the electric furnace is the cost of melting a solid charge; it is therefore most desirable to feed it with liquid metal. This leads to duplexing a cupola with an electric furnace, and several foundries are already operating in that way (for example, the Marquise, the Denain, the Mazières, the Firminy foundries). The additional expense *(Continued on p. 66)*



where replacements are costly

A STAMP MILL in a trackless Andean interior. . . . Picture the time and money losses involved in parts replacements under such circumstances! And yet there are literally thousands of nearby instances — in industrial, engineering, oil, mining and other projects — where replacement problems are no less serious . . . where inaccessibility, removal and installation difficulties, labor, transportation, shutdowns and what-not exact heavy tolls . . . where mechanisms ought to be qualified to let their users "put them to work and forget them."

Hence, where replacements are costly there should be no compromise with quality. . . . The unquestionable "best" in irons and steels is ultimately the least expensive. Toward attaining it the various alloying elements and combinations become a subject for intensive consideration. *There are hundreds of cases in which Molybdenum's addition to, or substitution for, other alloys has bettered products.* Results have proved that the increase in life is attained at the lowest possible cost.

Would you be interested in some substantiating facts and findings? WRITE for these books: "*Molybdenum in* 1934" and "*Molybdenum in Cast Iron* — 1934 *Supplement.*" Also keep informed on current "Moly" developments by asking to be put on the mailing list of our periodical news-sheet, "*The Moly Matrix.*" Feel free, too, to consult our metallurgists and to use our Detroit experimental laboratories on any alloy problems. Climax Molybdenum Company, 500 Fifth Avenue, New York. (In Canada: Railway & Power Engineering Corp., Ltd.)

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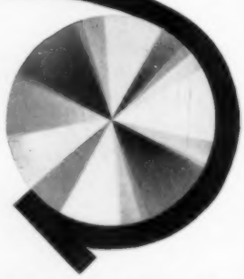

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CORRESPONDENCE

(Continued from p. 64) for rehandling liquid cast iron may be counterbalanced by increasing the proportion of scrap and foundry returns in the cupola mixture.

On the other hand, many small foundries will not undertake the expense of fitting up an electric furnace. They ask for raw materials that possess the required structure and purity mentioned at the outset, without an exaggerated increase in price. This may be supplied by iron companies who have installed an electric furnace at the blast furnace plant. Thus, the electric furnace finds its place before the cupola instead of after. It is also possible to recarburize bessemer steel to the desired degree. The foundryman then merely needs to melt electric pig irons, refined chemically (as to purity and low carbon) and structurally (as to finer graphite).

The cost of such an operation (treatment of the liquid pig iron and dilution with liquid steel) varies in the cases studied. For example, two principal circumstances may occur which, while they give technically equivalent results, are different from the point of view of economics. At a blast furnace producing only pig iron, where the electric furnace is used intermittently for the treatment of the liquid iron and dilutes it with cold steel scrap, the price increase of the refined mixture (cast iron plus steel scrap plus casual additions) is actually about 100 to 150 francs per ton of iron produced.

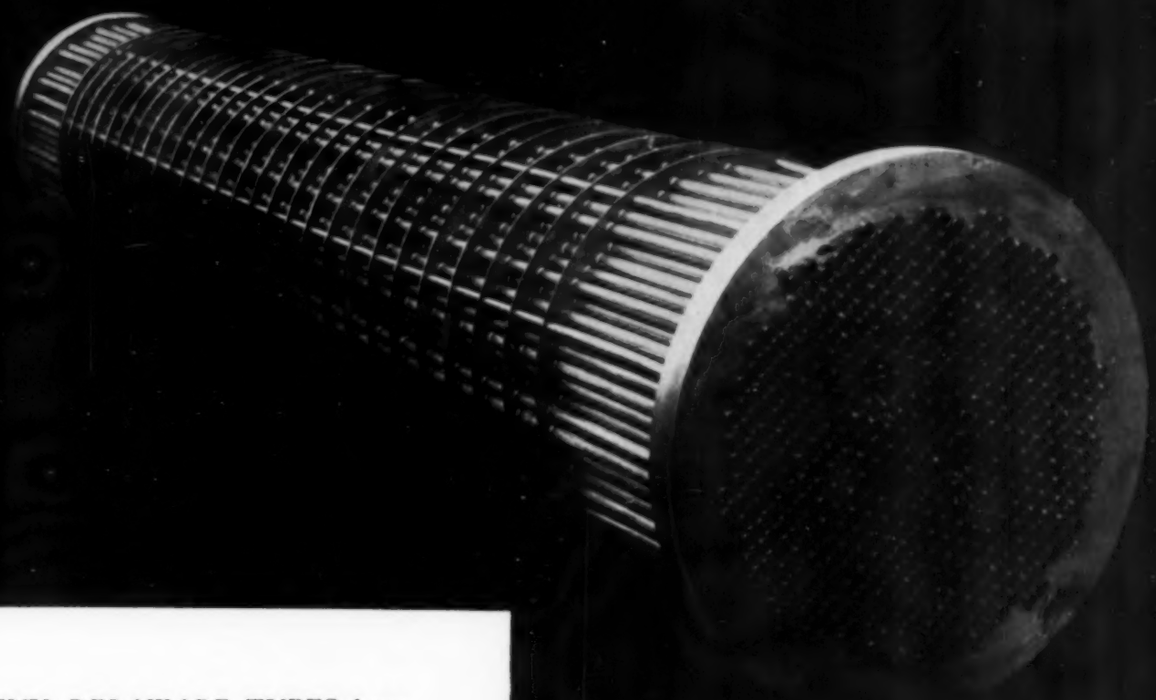
On the other hand, at a steel plant in the east of France it is easy to maintain the electric furnace in continuous operation either refining pig iron, or for duplexing with a Thomas converter. In this plant the refined pig iron may be diluted with liquid steel (the price of which, at the mouth of the converter, is not much greater than that of molten pig iron). The treatment in the electric furnace is then very speedy, and the product needs to carry a premium of no more than about 50 francs per ton.

In any case, one may see that it is already possible to purify molten pig iron in the electric furnace and to lower its carbon content so as to feed the cupola when high strength castings are ordered. This also requires a relatively small increase in price over the 250 francs now charged for foundry iron.

ALBERT PORTEVIN

(Additional letter on page 68)

THE NEWEST DEVELOPMENT IN ALLEGHENY SEAMLESS STEEL CONDENSER OR HEAT EXCHANGER TUBES



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CORRESPONDENCE

Nature of Shatter Cracks

URBANA, ILL. — In the excellent article by H. H. Ashdown on Surface Cracking printed in the May issue, the term "shatter cracks" is used several times to describe cracks produced on the surface of steel blocks by severe grinding. This is unfortunate, for this term has been used for years to describe a type of internal crack or shattered condition occasionally found in railroad rails. Numerous references to this type of defect are found in the technical literature. The following articles are typical examples: "On the Shattered Zones in Certain Steel Rails" by J. E. Howard, *Proceedings*, A.S.T.M., 1920, p. 44, and "The Relation of Shattered Steel in Fissured Rails to the Mill End of the Rail" by M. H. Wickhorst, *Proceedings*, American Railway Engineering Association, 1920, p. 216.

This type of internal crack is sometimes found in large steel bars as previously described and illustrated by Mr. Ashdown in the November 1933 issue of METAL PROGRESS. The term "flake" has usually been applied to these internal cracks because of the contrast in appearance between the internal crack and the refined grain structure of the surrounding metal when heat treated forgings or bars containing the cracks are fractured. There appears to be no essential difference between such flakes and the shatter cracks found in railroad rails except that in the latter case the structure of the metal surrounding the shatter cracks has not been refined by heat treatment; therefore they do not stand out so plainly when the rail is fractured. For this reason they have usually been located by deep etching a polished longitudinal section with strong acid and as so revealed appear as short, narrow cracks arranged in a haphazard manner.

It would seem logical that the term shatter crack could very well be applied to what has commonly been called flakes. In any event, since there are three terms which adequately describe the cracks produced by grinding, namely, grinding cracks, surface cracks or thermal checks, let us hope that the term shatter crack can be reserved as a specific name to apply to internal cracks representing a shattered condition of the metal in the interior of steel bars or forgings or rails.

R. E. CRAMER

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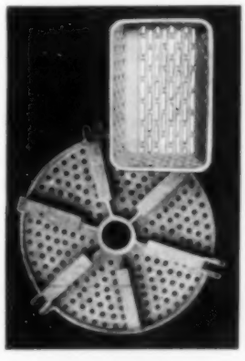

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Annealing Coiled Strip

How G-E bell-type furnaces for bright annealing coiled steel strip produce a uniform, high quality product is told by General Electric Co. in Bulletin Jyx-60.

Carburizing Retorts

Low cost, flexibility, uniformity, control, quality, and less labor with retort gas carburizing, says American Gas Furnace Co. Rotary, vertical and bell type retorts are described in Bulletin Jyx-11.

Diamond Wheels

The history of diamond wheels, their application to grinding and lapping cemented carbides and hard, brittle materials, and instructions for use are told by Norton Co. Bulletin Jyx-88.

Metallographic Polishing

The Guthrie-Leitz automatic polishing machine is designed to eliminate all elements of the human equation which make the hand preparation of metal specimens so undependable. Described in Bulletin Jyx-47.

S.A.E. Steels

The advantages of cold drawing in raising tensile strength and yield point are given in Union Drawn Steel Co.'s folder. It is accompanied by a copy of the newly revised S.A.E. steel specifications. Bulletin Jyx-83.

Phosphor Bronze

An interesting little history of bronze from antiquity to the present prefaces a complete description of the properties, composition, uses, and shapes available of Seymour phosphor bronze in a folder by Seymour Mfg. Co. Bulletin Jyx-48.

Surface Pyrometers

In many industries the determining of surface temperatures is of utmost importance. Pyrometer Instrument Co. describes their line of surface pyrometers and illustrates their simplicity in Bulletin Jyx-37.

Aluminum News

A cleverly written, well-illustrated newspaper of interesting items about aluminum is issued by Aluminum Co. of America every month. The latest issue is Bulletin Jyx-54.

Electric Furnaces

The electric furnaces made by Hoskins Mfg. Co. are well presented in their latest catalog. Contents include data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

Stainless Slide Chart

Carpenter Steel Co.'s pocket-size slide chart gives at a glance the technical data on all stainless steels. Bulletin Jyx-12.

Standard Burners

Surface Combustion Corp.'s burners are built in 47 different types and more than 400 different sizes. Descriptions and illustrations of many of them are given in Bulletin Jyx-51.

Burners and Valves

Auxiliary equipment for industrial furnaces that will insure proper heat production and correct combustion, such as oil and gas burners, blowers, regulating and shut-off valves, is fully described in Mahr Mfg. Co.'s illustrated booklet. Bulletin Jyx-5.

Alloy Castings

A new bulletin on corrosion and heat resisting alloy castings is offered by Michiana Products Corp., manufacturers of Fire Armor and Zorite and other heat and acid resisting castings. Bulletin Jyx-81.

Sensitive Controller

Unique features of Foxboro pyrometer controller which give it high sensitivity, essential for good control, are given in Bulletin Mx-21.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

Rockwell Tester

The Rockwell Superficial Hardness Tester is applicable to far thinner sheet and strip than the regular Rockwell. Its use for nitrided and case hardened parts is also described by Wilson Mechanical Instrument Co. in Bulletin Myx-22.

Welding Electrodes

Electrodes for welding alloy steel, particularly "Cor-ten" steel, used for railroad cars and outdoor structures, are described in Metal & Thermit's new booklet. Bulletin Myx-64.

Carbonol Process

The Carbonol process of carburizing is described in detail in a folder of Hevi Duty Electric Co. Results are said to be quicker, cleaner and better cases at very low cost. Bulletin Jy-44.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a leaflet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Tacks and Nails

Cut tacks and small cut nails (Grand Crossing Quality) of all types and for all uses are catalogued in Republic Steel Corp.'s latest booklet. An index is provided for handy reference. Bulletin Myx-8.

Centrifugal Compressors

B. F. Sturtevant Co. has a line of centrifugal compressors designed particularly for industrial furnace applications. These are illustrated and described in Bulletin Myx-58.

Safety in Oxwelding

A revised edition of "Precautions and Safe Practices" in the care and handling of oxy-acetylene equipment has been prepared by Linde Air Products Co. This booklet is regarded as a standard reference on this phase of safety in industry, and this latest edition contains some new suggestions required by advances in the oxy-acetylene process. Bulletin Mx-63.

New Hardening Method

The three vital factors in correct hardening are controlled by the new Vapocarb Hump hardening method, described in a Leeds & Northup bulletin. These factors are quench point, heating rate and furnace atmosphere. Bulletin No-46.

Silico-Manganese Steel

Silico-Manganese steel for heavy duty springs is the subject of Bethlehem Steel Co.'s new folder giving its properties and recommendations for heat treatment. Bulletin Jyx-76.

Tubing Weight Tables

Timken Steel & Tube Co. has issued a series of "Master Weight Tables" for round steel tubing, on letter size heavy paper, punched for binding. Weights per lineal foot of length are given for all sizes of hot finished and cold drawn tubing. Bulletin Mx-71.

Radium Radiography

Advantages of portability, ease of application and manipulation in examination of castings, forgings, molds, weldings, and assemblies are attributed to radium for industrial radiography. Details are given in a booklet issued by Radon Co. Bulletin Jx-56.

Turbo Compressors

The new items in Spencer Turbine Co's bulletin are a new and smaller "Midget" turbo for individual mounting, a single-stage line which effects new economies, and the gas-tight turbos for acid and explosive gases. Bulletin Mx-70.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Blast Cleaning

A centrifugal machine which cleans castings without the use of compressed air is the subject of Pangborn Corporation's new folder. How and why 1800 lb. of castings can be cleaned in 8 min. at low cost is told. Bulletin Jx-68.

Dark Room Layout

A novel card 9½x13 in. containing suggested arrangements for a photomicrographic dark room has been designed by Bausch & Lomb. Costs for installation are estimated, and on the reverse side are printed rules for using the dark room. Bulletin Jx-35.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Steel Shafting

Bliss & Laughlin has an attractive folder on their steel shafting, turned, drawn, ground, and polished to precision standards. Sizes and tolerances and uses are given. Bulletin Ax-42.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Manual of Pyrometry

Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

High Tensile Steels

Three types of high tensile steel particularly adapted to the transportation industries are described in a folder from U. S. Steel Corp. These are a chromium-copper-silicon steel for corrosion resistance, a medium manganese steel, and a strong structural silicon steel. Bulletin Mx-79.

Photocell Pyrometers

Recording potentiometers using a beam of light, a mirror galvanometer, and a photo-electric cell give instantaneous control with high sensitivity and accuracy. The different varieties made by C. J. Taglibue Mfg. Co. are described in a 16-page letter-size booklet. Bulletin Fx-62.

Metameter

Information on Bristol Co.'s Metameter, which makes it possible to control temperatures, pressures, levels, and other process conditions or operations at any distant place, is contained in Bulletin Ax-87.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue by asking for Bulletin Ax-4.

Alloy Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resisting steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Nv-38.

Everdur

Properties, applications, and forms available of this copper-silicon-manganese alloy are described by American Brass Co. High strength and corrosion resistance, ductility, weldability, workability, and moderate price are some of the advantages featured. Bulletin Dc-89.

Cyanides and Salts

R & H Chemicals Department of E. I. du Pont de Nemours Co. has a new 28-page manual on the procedure for case hardening, reheating, nitriding, and mottling of steels with cyanides, and on coloring, tempering, and drawing with salts. Nv-29.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data regarding application to various types of furnaces are given in Bulletin Fx-57.

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WHAT TO READ

Reviews

Metallurgy 1910-35, H. C. H. Carpenter, Engineering, May 3 (Jubilee Section), p. 16 . . . . Twenty-Five Years of Physical Metallurgy, J. M. Robertson, Iron & Coal Trades Review, May 3, p. 746 . . . . Alloys — Old and New, H. C. H. Carpenter, (Paper for Iron & Steel Institute) Engineer, May 10, p. 492.

The Steel Industry, Sir Robert Hadfield, Engineering, May 3 (Jubilee Section), p. 18 . . . . Contemporary Progress in Steel Industry, J. F. Shadgen, Iron Age, May 2, p. 26.

Iron Ore and Melting

Direct Reduction of Ores, An Appraisal, R. S. Dean, Mining & Metallurgy, April, p. 185 . . . . Silica and Alumina in Iron Ores, T. L. Joseph, Blast Furnace & Steel Plant, May, p. 313.

Some Observations and Theory on Slack-Wind Blast Furnace Operation, F. M. Rich, A.I.M.E. Tech. Pub. 617, Metals Technology, April . . . . External Heat Loss of Blast Furnaces, D. F. Marshall, (Paper for British Iron & Steel Institute), Engineering, May 10, p. 503.

Innovations in Open-Hearth Technique, The Iron Age, April 18, p. 24 . . . . Ladle and Teeming Practice in the Open-Hearth Department, G. D. Tranter, A.I.M.E. Tech. Pub. 618, Metals Technology, April . . . . Effective Insulation of Open-Hearth Furnaces, Gilbert Soler, Steel, April 15, p. 62 . . . . Practical Points on Open-Hearth Melting, Steel, April 22, p. 46 . . . . Progress in Steel Making Reported From Germany, S. Epstein, Metals & Alloys, May, p. 113.

The Oxidizing Power of Basic Slags, J. White, Paper for British Iron & Steel Institute, May Meeting . . . . Residual Metals in Open-Hearth Steel, J. D. Sullivan, Metals & Alloys, May, p. 134.

Non-Metallic Inclusions in Ferro-Alloys, B. Matuschka, (Paper for British Iron & Steel Institute), Iron & Coal Trades Review, May 3, p. 764.

Melting Metals Electrically, G. H. Hall, Electrical World, May 11, p. 25 . . . . Melt Metals With Natural Gas, Pat Dwyer, Foundry, May, p. 24 . . . . Development of the Coreless Induction Furnace, G. H. Clamer, Metals & Alloys, May, p. 119.

Heat Treatment

Modern Heating Machines, C. W. Swenson, Industrial Gas, May, p. 16 . . . . Heating, Quenching and Drawing in Automatic Furnaces, J. B. Nealey, Machinery, May, p. 526 . . . . Selection and Management of Gas and Oil-Fired Heat Treatment Furnaces, G. H. Barker, Metallurgia, April, p. 145.

Accurate Annealing, E. F. Lake, Heat Treating & Forging, April, p. 177 . . . . Normalizing Process Reduces Internal Stress in Rails, John Brunner, Railway Age, April 2, p. 325.

Controlled Atmospheres for Heat Treatment, Steel, April 22, p. 39.

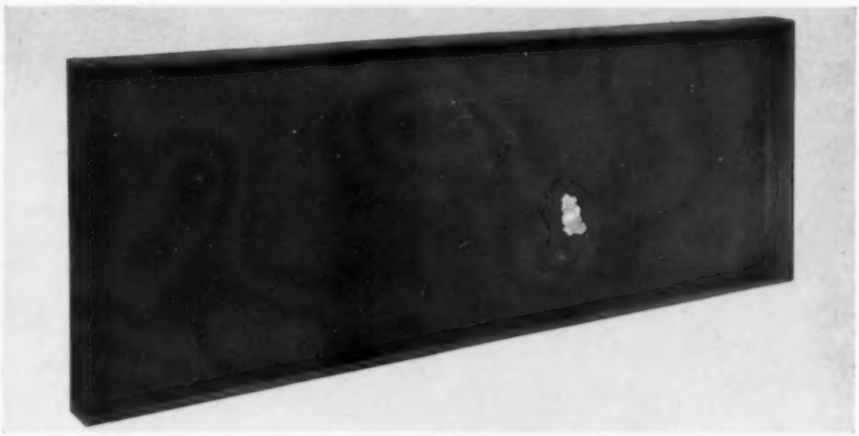
Heat Treating Packard Axle Shafts, Iron Age, May 2, p. 24.

Rolling, Pressing, Forging

Eliminating Surface Defects at the Ingot, R. V. Wallace, Blast Furnace & Steel Plant, April, p. 251 . . . . Electrical Aids to Precision Rolling of Steel, H. A. Winne, Iron Age, March 28, p. 18 . . . . Electric Power Equipment for Steel Plants, R. H. Wright, Electrical Engineering, May, p. 481 . . . . Deflection of the Rolls in Plate, Sheet, and Strip Mills, J. S. Caswell, Paper for British Iron & Steel Institute, May Meeting.

(Continued on page 74)

THERMALLOY HEARTH PLATES



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(Continued on page 76)

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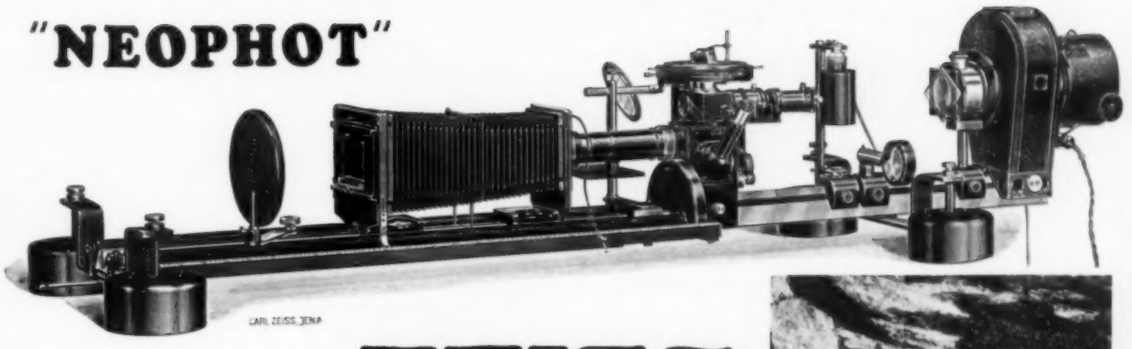

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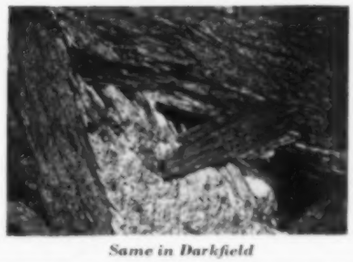

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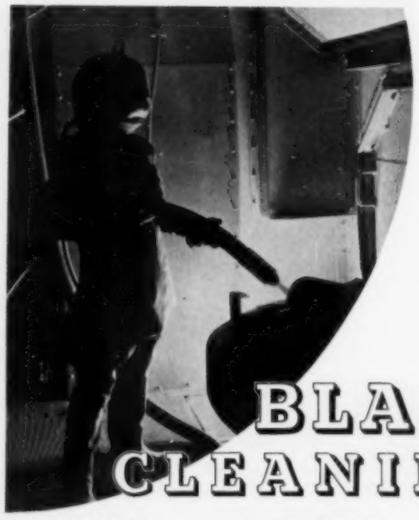

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METAL HOUSES

(Continued from page 58) enameled iron. In one very notable example of this type of construction the entire exterior was formed of vitreous enameled iron, backed up with a special cement, forming easily handled building units. These were fastened by means of cast-in anchor hooks to a steel skeleton made of parts pressed from 16-gage sheet. Between sections were mortar joints $\frac{3}{16}$ in. thick, raked back and pointed with mastic cement. Insulation was effected by filling the wall spaces with rock wool. Large numbers of spectators passed through and inspected this house every day during its two years at the Exposition. Its beauty, its never-fading colors, its hard, smooth surfaces, and its ease of cleaning have been approved by thousands.

Hardly any popular center but has one to several houses (the product of wide-awake and enterprising builders) which use notable amounts of metal either in frame, floors, or siding. An even greater use is in service stations, lunch rooms, and store fronts. A recent typical news note was to the effect that one of the mid-continent oil companies had ordered $100,000 worth of standardized service stations, each one to contain about 15 tons of steel sheet, enameled iron, and stainless trim.

Unlike the stainless steel development, the vitreous product has not yet advanced to use on a major building. The influence, however, that these many small structures have exerted may yet presage the way to its use in a major building during the next decade, for it possesses so many desirable qualities. Even now, one sees many smaller commercial buildings whose "faces have been lifted" by covering the drab, weather-beaten exterior with well-designed and harmoniously colored panels of enameled steel.

A great market for both stainless steel and vitreous enameled iron is thus seen, developing a market which has not hitherto been enjoyed by steel products. The future for these materials seems full of promise, especially if the prevailing prejudices against metal in small buildings can be overcome. This development is awaiting only the impetus to be derived from the long-delayed revival of construction, when numberless customers can be convinced of the essential and long-time economy of metal exteriors for modern buildings.